G-Explorer Scintillation Counter

(Gamma-Explorer – Geo-Explorer)

User Manual V1.0

13.07.2011

CONTENTS

Preface 4
General 4
System Package 4
Preparing For First Use 6
For a long useful life 7
Startup 8
How G-Explorer Works 11
Operating G-Explorer 11
The set measuring range simultaneously acts as the alarm threshold!! 11
G-Explorer‘s operating controls 12
Available Functions 13
Using Gross Ips Mode 14
Submenu 15
Storing values an SD card 15
Automatic Recording 16
Manual recording 16
Recording external measurements 17
Setting distance 17
Using the file command 17
Adjusting the Offset 17
Setting a minimum- maximum 18
Setting upper and lower limits 18
Switching to impulses per minute 18
Dose Rate Mode 19
Submenu 19
Set Duration Mode 21
Set Impulse Mode 22
Gamma spectroscopy 22
Setup 23
Setting screen contrast 23
Accessing Services 23
Setting the time 24
Default setting 26
Battery charge state 26
Working with Data 27
GPS-Receiver Option 32

 © ROM-Elektronik GmbH

Technical Documentation 34
Rear Panel Connections 34
Front Panel Connections 34
Multifunction port 35
Radioactive Radiation 36
Ionizing radiation 36
About radioactive radiation 37
PARTICLE RADIATION (CORPUSCULAR RADIATION) 37
QUANTUM RADIATION (ELECTROMAGNETIC RADIATION) 37
Alpha(α-)radiation 37
Beta(β-) radiation 38
Neutron radiation 38
Gamma(γ-)radiation 39
X-ray radiation 39
Radioactivity measuring units 39
Half-life 41
Natural Radiation Exposure 41
Tiles and Flagstones 48
Recommendations 48
Measuring Radon 49
Summary of the Measurement Procedure 49
The measuring filter 50
Measure The Background radiation 50
Vacuuming 50
Calibrate the Vacuum Cleaner 51
Calculate the air flow in m^3/min: 51
example 1 51
example 2 52
measure the filter 52
do the analysis 52
more measurement tips 53
Analyzing a G-Explorer radon test 53
remarks: 53
Analysis examples 54
example 1 54
remarks 54
example 2 54
remarks: 55

PREFACE

This technical manual has been designed for users who have previous experience in working with instruments that measure radioactivity.

We intend to continually refine the G-Explorer with new features. To ensure that these improvements meet your requirement, we need your feedback. Please send us your ideas for improvements and other suggestions, preferably in an email to

info@rom-elektronik.com

so that we can consolidate and, if appropriate, implement them..

We also ask that you send us as detailed a description as possible of the problem if you experience any difficulties with the instrument or in using this manual..

As we publish new control programs and user manuals periodically, we will make them available for free download from:

www.rom-elektronik.com

General

G-Explorer is a universal radioactivity measuring instrument with a scintillation detector. G-Explorer detects elevated radiation levels in an especially rapid and reliable manner. It is a next-generation, follow-on product to our proven medCONT radiation measuring system, which has been and is still used today primarily in geological field surveys. Hence this handbook focuses mainly on that sector.

Nonetheless, G-Explorer provides full-spectrum functionality for measuring radioactivity..

Explorer features null effect automation; by supplying a constantly updated, measured background radiation value (null effect at the detector) it frees the user from the chore of measuring null effects.

G-Explorer can rapidly and accurately detect even minute amounts of radioactivity in the nuclide lab, environment, ground, building materials or foodstuffs. Gamma spectroscopy is available as an option.

System Package

The system package includes:

- G-Explorer
- NaI detector 2“ x 2“
- Lead collimator
- Detector cable
- Batteries
- Carrying case
- User Manual

Other parts can be purchased as accessories..

 © ROM-Elektronik GmbH

G-Explorer technical data:

Readout Range:	0-10,000 ips or ipm (impulses per second or per minute) 0-10,000 nSv/h
Readout:	Graphic liquid crystal display; LEDs for “On”, “USB” indicators
Operating temp.	-5° C to 40° C
Dimensions:	185 mm x 135 mm x 35 mm (LxWxH)
Interfaces:	Serial port, USB, SMA analog output 0 – 2.5 V, multi-function interface (GPS, etc.) detector port, SD-card
Weight:	Approx. 800 gram
Power supply:	4 “AA” 1.5 V batteries; or rechargeable battery pack
Max. battery life:	8 – 10 hours

Technical data: NaI detector

Type:	2” x 2” NaI(Tl) scintillation detector housed in a lead collimator
Radiation type:	Gamma
Operating temp.	-5° C to 40° C
Storage temp.	-10° C to 70° C
Dimensions:	120 mm (diameter) x 340 mm
Weight	Approx.. 8,000 gram (with lead collimator)

We reserve the right to change technical specifications.

Safety precautions

1. Connect and disconnect the detector only while the G-Explorer is turned off.

2. Caution!!! When the instrument is on, the detector port carries a high voltage charge.

3. The housing should only be opened by qualified technicians.

PREPARING FOR FIRST USE

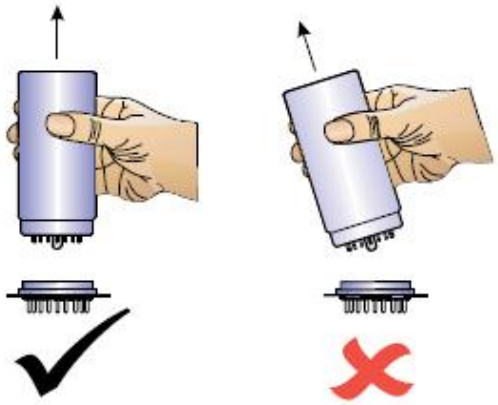
Prior to using G-Explorer for the first time, you must mount the delicate NaI scintillation detector in the lead collimator. To do so, first unscrew the lead collimator's cover.

On its underside you will see a socket where the prongs of the NaI detector's photomultiplier plug in. Make sure to position it correctly. The detector base has a nub on it that fits into the a slot on the socket.

The nub on the detector's base..

 © ROM-Elektronik GmbH

Apply a small amount of gentle pressure to insert and remove the detector. Make sure that the base's prongs line up vertically with the socket when doing so.



When assembled correctly, the combination of detector and socket will look as pictured here. Next, carefully screw the assembly into the lead collimator.

For a long useful life

The photomultiplier of the medCONT NaI detector is made of fragile glass. It is extremely delicate! Beware of knocking or hitting the detector against anything and do not subject it to temperature swings exceeding 5°C per hour!

Startup

The G-Explorer works with 4 “AA” batteries; alternatively, it can be powered by NiCad or NiMH rechargeable battery packs..

Using the edge of a suitable coin, turn the battery compartment cover clockwise to open it. Insert four fresh batteries or battery packs into the battery holder, taking care to align their poles correctly.

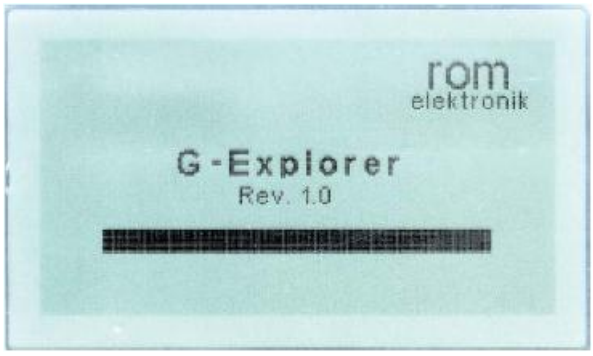
Insert the battery holder half-way into the battery compartment. Attach the battery connector, push the battery holder all the way in again and close the battery compartment..

 © ROM-Elektronik GmbH

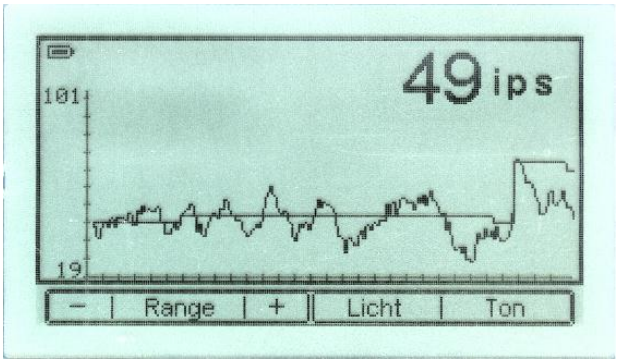
Next, connect the detector to the G-Explorer with the supplied detector cable. Insert one end of the cable into the receptacle on the lead collimator and the other end into the port on the G-Explorer. When not affected by high humidity or moisture, this cable conducts high voltage current (approx. 600 – 1,000 V) to the detector!

If you haven't already done so, switch the instrument on.

The red status indicator (embedded in the ROM logo) comes on, and a splash screen appears in the display;



G-Explorer now switches automatically into the operating mode in effect before the last shut-down. The factory default mode is set to "Gross IPS".



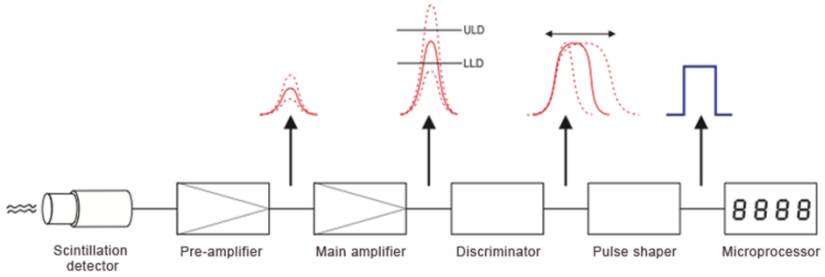
The screen shows the current measured value as the number of impulses (i.e., counts) per second (ips or cps) and a graph that shows how the measured values varied over time.

This means that your G-Explorer is working properly..

 © ROM-Elektronik GmbH

How G-Explorer Works

G-Explorer is a universal radioactivity measuring instrument with a scintillation detector. The following illustration shows its basic functioning:



The radioactive waves strike the NaI(T1) scintillator crystal, which emits light pulses when it detects incoming ionizing radiation (x-rays and gamma rays). These light pulses, which convey information about the radiation's energy level and strength, are converted into electrical impulses that then can be quantified electronically. A low-noise pre-amplifier boosts the signal, and then the main amplifier raises it to a level approaching that of the feeder current. A single-channel voltage comparator (discriminator) with adjustable lower- and upper-level discriminator limits (abbreviated LLD and ULD, respectively) makes it possible to measure the entire energy range or only a select part of it. Take Cesium-137, for example; it emits energy of 662 keV. If we set the lower and upper threshold around say 662 KeV ± 15keV, then only radioactivity with energy around 662keV will be measured.

After passing through the discriminator, a pulse shaper turns the signal into a microprocessor-readable signal for digital read out.

Operating G-Explorer

The key pad lets users select the various functions and operating modes of the G-Explorer.

Each of the function keys F1

through F4

, and the Menu

and CR

keys have specific functions assigned to them. Depending on the operating mode, various functions that can be activated by pressing F1 through F4 are displayed along the bottom edge of the screen. This provides quick access to the most frequently used settings.

In the "ips" operating mode, F1 and F2 are used to set the measuring range in the display. Pressing F1 lowers the upper limit of the displayed range while pressing F2 raises it. The longer the key is held down the higher the step increment will be, so that large adjustments can be made quickly.

The desired range can also be entered via the key pad after F1 or F2 have been pressed..

The G-Explorer waits about 5 seconds before accepting the entered values. By pressing the "CR" key, the user for whom this is taking too long can instantly return to operating mode.

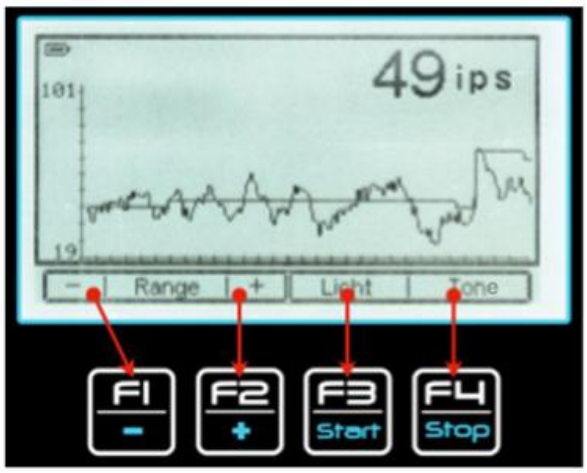
If the measured value registers above the set measuring range, an audible tone is generated and the screen will blink.

The set measuring range simultaneously acts as the alarm threshold!!

F3 turns on the screen's backlight. The key can be pushed up to three times to increase the

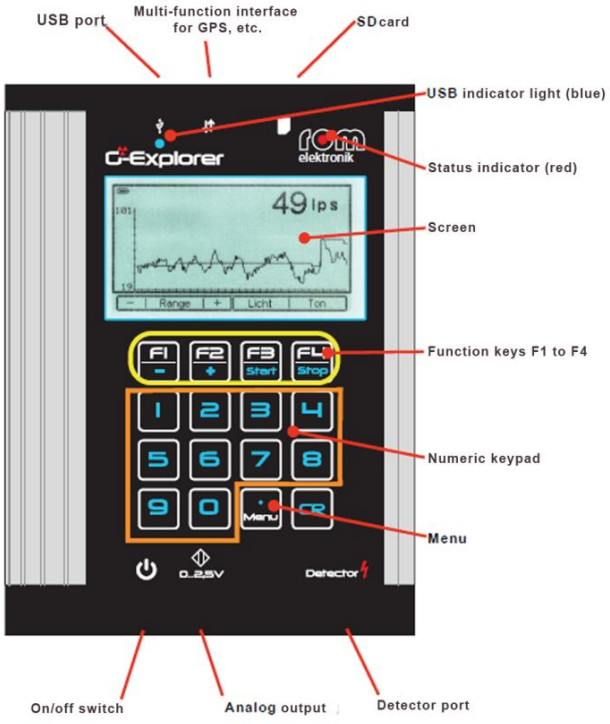
brightness incrementally; after that the screen goes dark..

F4 turns off the alarm tone. In normal mode, pushing F4 makes the detector signal audible (each impulse produces one beep; simultaneously, the red status indicator light embedded in the ROM logo will blink in rhythm with the detector's pulsing). Pushing F4 again produces a rhythmic signal, representing the internal measuring time. One more push on F4 shuts off the speaker..



Press the Menu key to open a "submenu" from which you can access the main menu. Pressing the CR key confirms inputs.

G-EXPLORER'S OPERATING CONTROLS



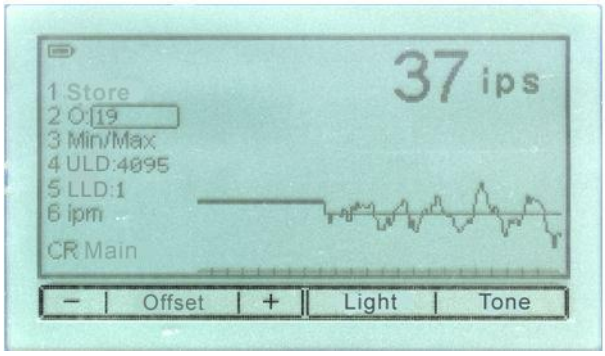
 © ROM-Elektronik GmbH

Available Functions

G-Explorer's offers the following operating modes, explained in detail below:

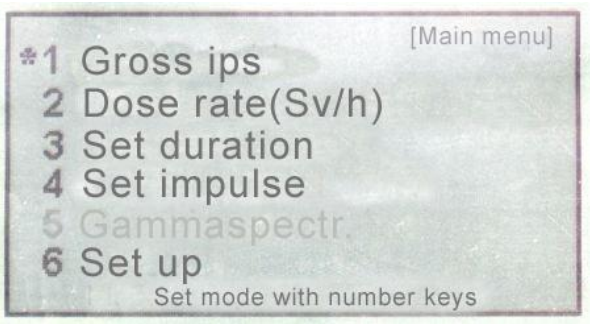
- Gross ips
- Dose rate
- Set duration
- Set impulse
- Gamma spectroscopy (optional)

Access the operating mode menu with the Menu key. Push it once to open a submenu on the screen's left.



Pushing the CR key next will open the main menu.

From here you can choose the desired operating mode with the respective number key.

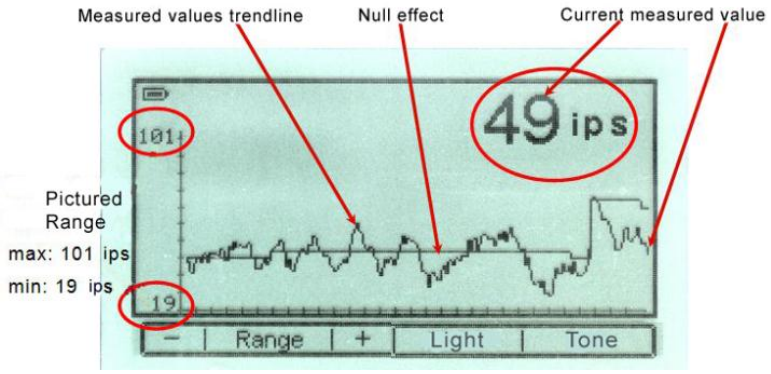


USING GROSS IPS MODE

This is the most frequently used mode in which the total number of impulses determines the measured value:

Measured value[ips] = Gross impulse rate [ips].

G-Explorer's on-board computer closely monitors every change in the frequency with which impulses hit the detector and adapts the measuring interval so as to minimize measurement errors. The graphic display also shows the null effect (=natural background radiation).



The null effect (background radiation) is constantly being calculated from the long-term, constant part of the measurement values and conformed as necessary. This makes it easy to recognize variations in measured values vs. the background radiation in the graphic display.

When consistently high readings are being recorded the graph line displayed in the screen's upper region will be relatively flat. In that event, variations from the null effect will barely register or not at all.

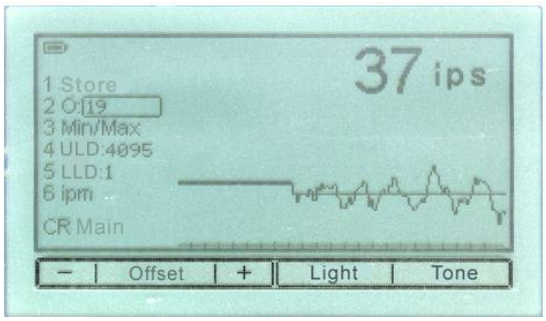
Keys F1 and F2 adjust the limits of the measuring range being displayed. Pressing F1 lowers the upper limit, while F2 raises it. Keeping the key depressed for a time will accelerate the setting change incrementally, making it possible to make large adjustments rapidly. It is also possible to enter the desired range directly via the numeric key pad after pressing F1 or F2.

The G-Explorer waits about 5 seconds before accepting the entered values. If this seems too long, the user can return instantly to operating mode by pressing the "CR" key.

If the measured value registers above the set measuring range, an audible tone is generated and the screen will blink. **Setting the measurement range simultaneously sets the alarm threshold!**

To deactivate the signal, adjust the lower display range limit from the menu.

 © ROM-Elektronik GmbH



Pressing the Menu key opens a submenu on the left side of the screen display. To select O(ffset) for the measurement display, use the "2" key and then adjust the setting with the F1 and F2 function keys.

Submenu

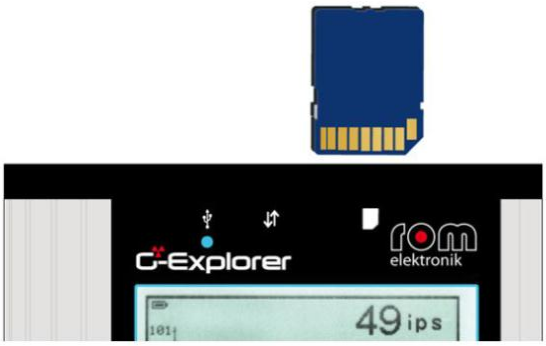
The submenu provides access to additional options in each operating mode. Select them in the open submenu with the numeric keys and adjust settings as required with other keys. The submenu lets you access the following options:

1. Storing measurements on an SD-card (if available and plugged in).
2. Setting the Offsets for the displayed measurement value
3. Activating a minimum-maximum display.
4. Setting an upper limit for gamma radiation energy (ULD)
5. Setting a lower limit for gamma radiation energy (LLD)
6. Switching to the impulses per minute (ipm) unit, useful when the impulse rate drops below 3 ips, for example.
7. Jumping to the main menu

To exit the submenu and return to measuring mode, push the menu key again.

Storing values an SD card

To record measurements, first insert an SD-card that has been pre-formatted for FAT32 in the card slot. Make sure that write protection is not enabled.

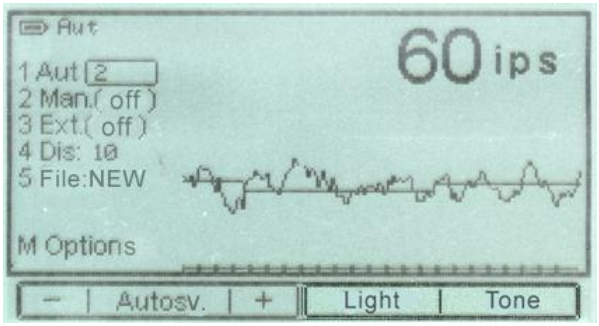


Submenu item 1 lets you specify alternative ways of storing measured values, as well as other settings:

1. Automatic recording at pre-selected intervals
2. Manual recording at the touch of button
3. Recording via an external clock signal (for example, from a surveyor's wheel with pulse generator)
4. Entering a distance (e.g., 10 meters)
5. Start a new data file (for example, for a new survey or location)

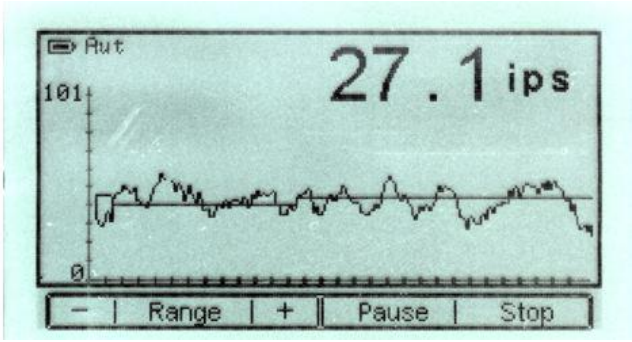
Automatic Recording

Recording measurements automatically is the most convenient method. Menu item 1 lets you choose the time interval at which recording is to take place each time; for example, every second or every 2 seconds, and so on.



.

Choosing 0 seconds causes every measuring cycle to be recorded so that every calculated measurement value is recorded. Press the Menu key twice to return to the measuring operation.



.

The recording mode appears in the screen's upper left corner ("**Aut**" for "automatic") and is activated by pressing F3 ("Start"). Once started, the unit (ips) blinks to indicate that measurements are being recorded. F3 pauses recording ("Pause") and F4 ("Stop") ends it..

Manual recording

Each push on the "CR" key records a measurement manually. The procedure is similar to that for automatic recording. The recording mode ("**Man**" for "Manual") is shown in the upper left corner of the screen and is invoked by pushing F3 ("Start"). Once started, the unit (ips) blinks to indicate readiness to record; however, only when depressing "CR" will a measurement data point be recorded.

F3 pauses recording ("Pause") and F4 ("Stop") ends it.

 © ROM-Elektronik GmbH

Recording external measurements

In the external recording mode, a measurement is recorded every time an external impulse is received. This is useful when working with a surveyor's wheel equipped with a pulse generator.

The procedure is similar to that for automatic recording. The recording mode ("**Ext**" for "External") is shown in the upper left corner of the screen and is invoked by pushing F3 ("Start"). Once started, the unit (ips) blinks to indicate readiness to record; however, only measurements based on an external impulse will be recorded. F3 pauses recording and F4 ("Stop") ends it.

Setting distance

Use the "Distance" menu item for documenting measurement distance, which can be a useful reference later on for further analysis..

Using the file command

Use the "File" menu item to specify if a NEW data file is to be opened for recording or if you want the existing (OLD) file to be written to. This can be advantageous when surveying large areas. The area is set up as a file, and each measurement series is recorded to it. Press F4 ("Stop") to end a series and start a new one with F3 ("Start").

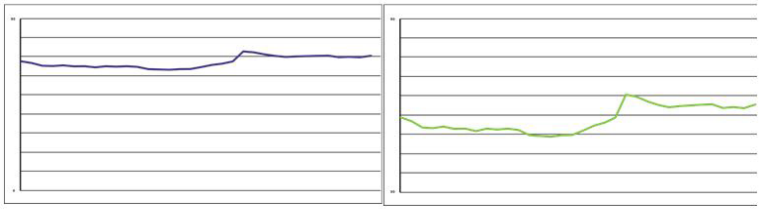
If the menu item "File" is set to OLD (ALT), the individual measurement series entered in the file will be separated by the notation "ADD"; in other words, a line containing "ADD" will be inserted with every "Stop"-"Start" sequence

Measurement file entry	Explanation
80;0.5;N=48.15.5758;E=010.19.7234	Most recent data (80 and 81) with GPS coordinates
81;0.5;N=48.15.5758;E=010.19.7234	
ENDE	Recording ended
15.06.11	on15 June 2011
14:05:39	at 14:05 and 39 seconds
GEX	New data from G-Explorer
D=10	At a distance of 10 (units)
15.06.11	on 15 June 2011
14:25:38	at 14:25 and 38 seconds
ADD	added
1;53.3	New measurement series data (1, 2, 3,….)
2;56.8	Most recent data (80 and 81) with GPS coordinates
3;56.2	

Adjusting the Offset

This menu item allows a certain amount of offset to the y-axis. Consistently elevated measurements will cause the graph line displayed in the upper part of the screen to be relatively flat. In that case, variations from the null effect will register barely or not at all.

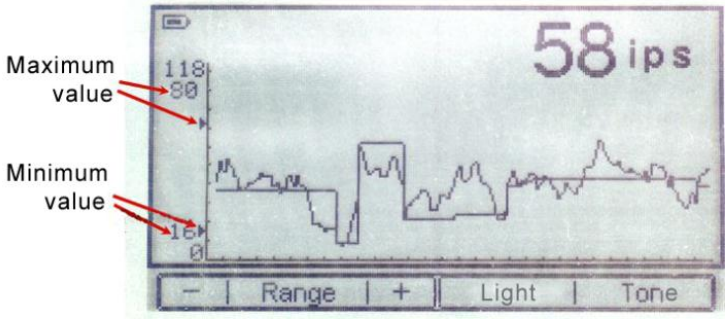
To fix this, adjust the lower display range using the menu. Use the "2" key to choose the [O]ffset to the measurement display and change it as necessary with function keys F1 and F2.



Setting a minimum-maximum

In this mode, the measured value's spread can be determined, with maximum and inimum values displayed on the y-axis.

The minimum and maximum values, respectively, will be activated each time a new low or high measured value is hit, provided it is statistically significant.



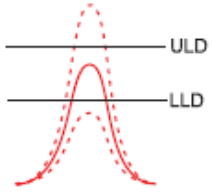
This operating mode makes it possible to observe by how much the radioactivity fluctuates.

Setting upper and lower limits

Use these two parameters to define an "energy window". In technical jargon this function is known as a Single Channel Analyzer (SCA).

The OG parameter sets an upper limit (threshold, ULD = Upper Level Discriminator). Impulse levels coming from the detector that exceed the set threshold will not register. The impulse is not counted.

The UG parameters sets a lower limit (threshold, LLD = Lower Level Discriminator). Impulse levels from the detector that come in under the threshold will not register. The impulse is not counted.



ONLY impulses will be counted that fall between the two set thresholds (window comparator).

Taking Cesium-137 which emits an energy of 662 keV as an example, if we set the lower and upper threshold at say 662 KeV ± 10keV then ULD = 672 keV and LLD=652 keV, and only radioactivity with an energy around 662keV will be measured..

Switching to impulses per minute

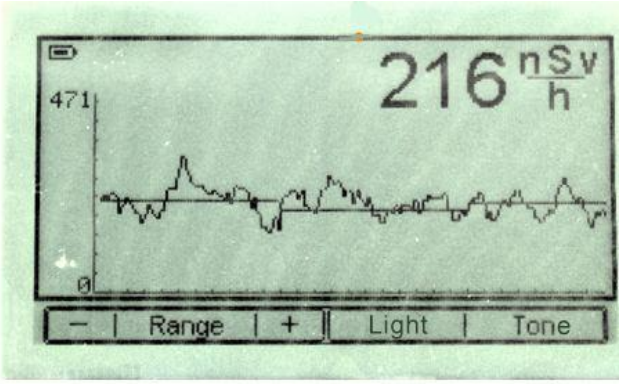
Switching to the impulses per minute (ipm) scale is useful should the impulse rate drops below 3 ips, for example.

 © ROM-Elektronik GmbH

DOSE RATE MODE

In this mode, the total impulse number is multiplied by a calibration coefficient to calculate a masured value.

Measured value [nSv/h] = gross impulse rate [ips] x calibration coefficient



The preferred way of doing this measurement is **without a lead collimator.** You therefore will need to unscrew the detector from the lead collimator. When measuring, be careful to hold the detector directly (NOT by the socket handle).

The reference value for the 2” x 2” NaI detector is 100 ips ≈ 100nSv/h

[Radiological note: For the population of the Bavarian alpine piedmont, the median radiation exposure of ca. 100-150 nSv/h, including exposure to radon and medical diagnostic radiation, led to cancer or leukemia in approximately 3 out of 1,000 persons over their life span (statistical reference value).]

Use keys F1 and F2 to adjust the limits of the displayed range. Pressing F1 lowers the upper range limit, while F2 raises it. Keeping the key depressed for a time will accelerate the setting change incrementally, making it possible to make large adjustments rapidly. It is also possible to enter the desired range directly via the numeric key pad after pressing F1 or F2.

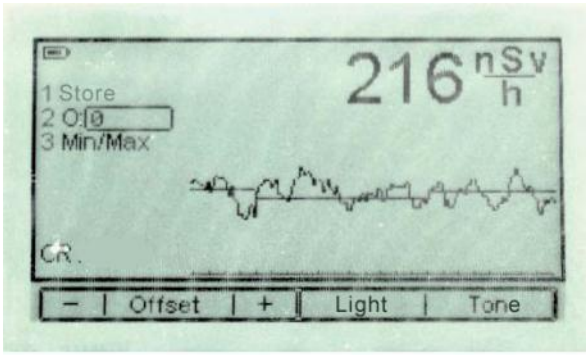
The G-Explorer waits about 5 seconds before accepting the entered values. If this seems too long, the user can return instantly to operating mode by pressing the “CR” key.

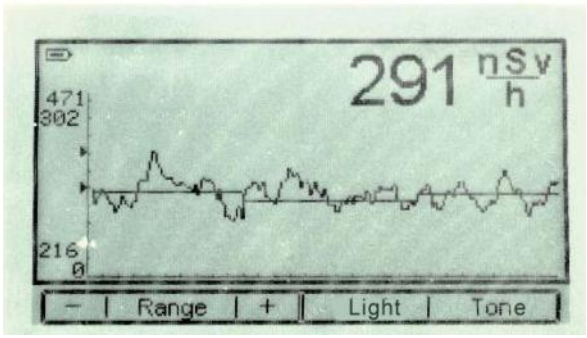
If the measured value registers above the set measuring range, an audible tone will sound and the screen will blink. **Setting the measurement range simultaneously sets the alarm threshold!**

Submenu

The sub menu lets you access the following additional options:

1. Storing measurements on an SD-card (if available and plugged in).
2. Setting the Offsets for the measurement value display
3. Activating a minimum-maximum display.





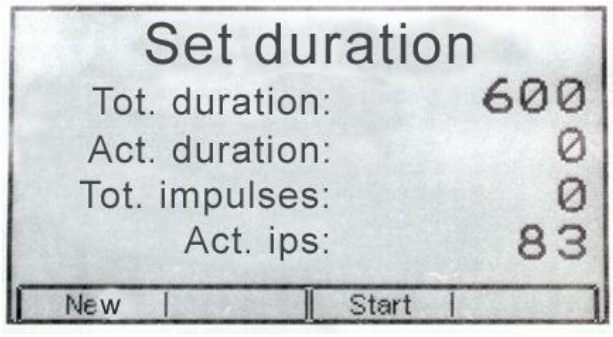
 © ROM-Elektronik GmbH

SET DURATION MODE

The duration setting lets you take measurements such as those that Geiger-Müller counters were used for. It is still useful today for measuring samples of, for example, paper filters, food stuffs, etc.

Enter the measurement duration either with F1 or F2 or directly on the key pad, then enter it by pressing the "CR" key.

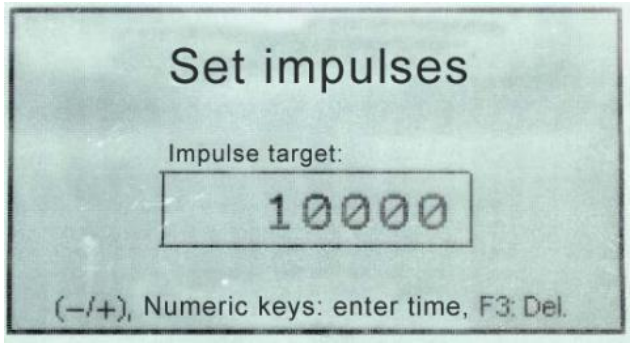
Conduct stationary measurement of a surface to be checked in step-wise fashion, that is, measure it segment by segment; press F3 to start the next measurement as you position the detector on each new segment.



Once the preselected duration has expired, the measurement will be presented on the screen. You will get the current measuring duration, impulse count and current measured value in ips.

This measuring mode does not provide for any other operations, such as storing data.

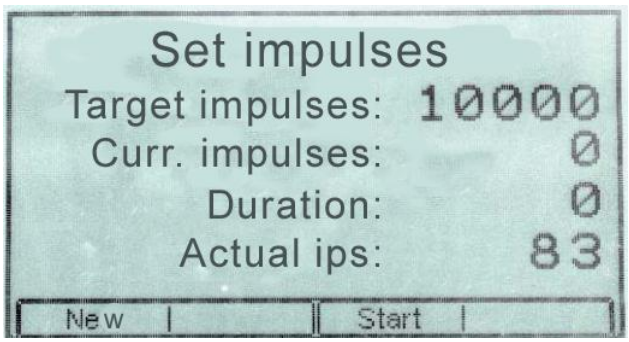
SET IMPULSE MODE



The impulse setting function lets you take measurements such as those that Geiger-Müller counters were used for. It is still useful today for measuring samples, for example of paper filters, food stuffs, etc..

Enter the target impulse number either with F1 or F2 or directly on the key pad, then confirm your entry with the “CR” key.

Conduct stationary measurement of a surface to be checked in step-wise fashion, that is, measure it segment by segment; press F3 to start the next measurement as you position the detector on each new segment.



The measurement will be presented on the screen once the preselected duration has expired. You will get the current impulse count, time expired and current measured value in ips. This measuring mode does not provide for any other operations, such as storing data.

GAMMA SPECTROSCOPY

Gamma spectroscopy is not included in the standard system package (and is therefore greyed out on the screen); but it can be ordered as an additional option, even after the initial purchase. It comes with its own user manual.

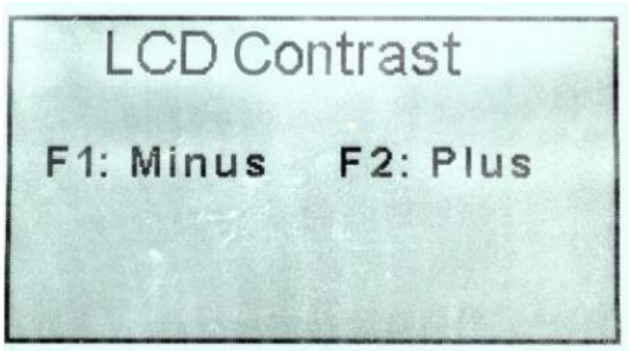
 © ROM-Elektronik GmbH

SETUP

Setup is for managing basic settings such as screen contrast and the G-Explorer's factory settings. "Default" restores the G-Explorer to its factory settings and returns it to its "as delivered" state.

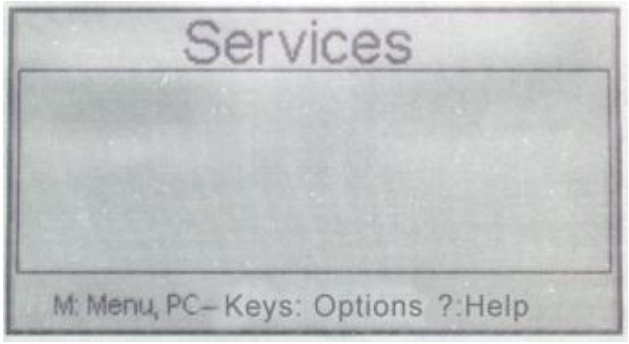
Setting screen contrast

Menu item 1 lets you adjust the screen contrast; use keys F1 and F2 to fine-tune it to your individual preference. To exit the menu, press "CR".das Menü verlassen.



Accessing Services

The "Services" menu item allows seldom-used options to be set or executed.



This function is likely to be used most often to synchronize clocks with a connected PC.

Setting the time

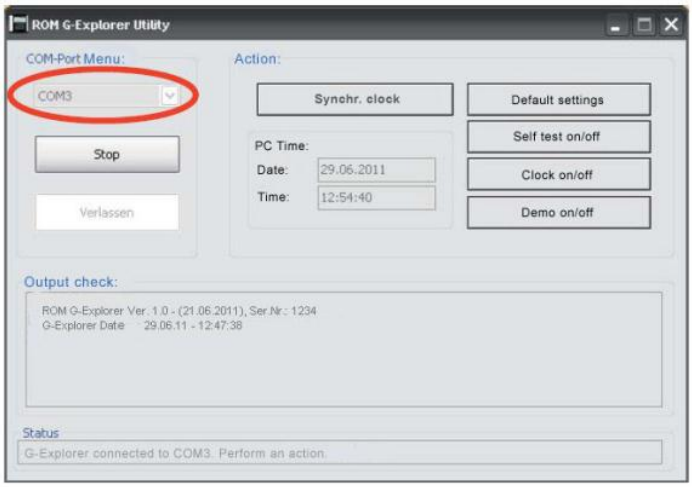
G-Explorer has a built-in real-time clock so that measurement data can be written to a memory card with the current date and time. To set the clock, G-Explorer must be connected to the PC via USB cable. When the PC is turned on, the G-Explorer's blue indicator light comes on. Select "Services" on the menu.

A utility software package is available for the G-Explorer on an SD-card, CD-ROM or from our web site, www.rom-elektronik.com.

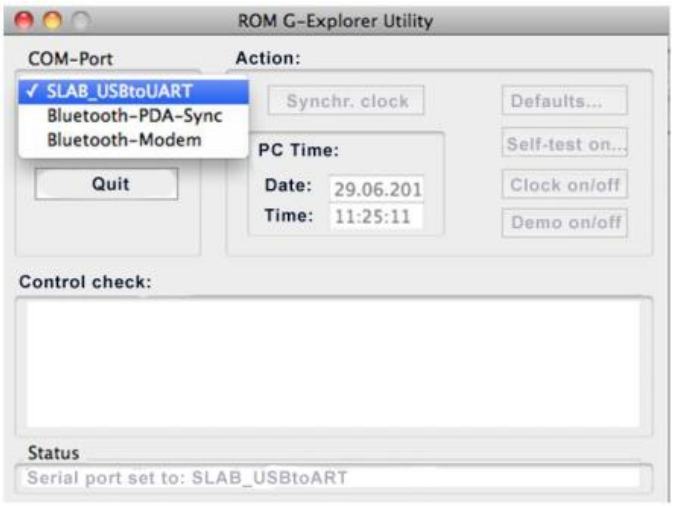
Before using the software, first correctly install the interface driver. As the install procedure varies for the different operating systems, we do not go into it here. Please consult the documentation for the relevant driver software.

Once the software is running, you must select the correct communications port.

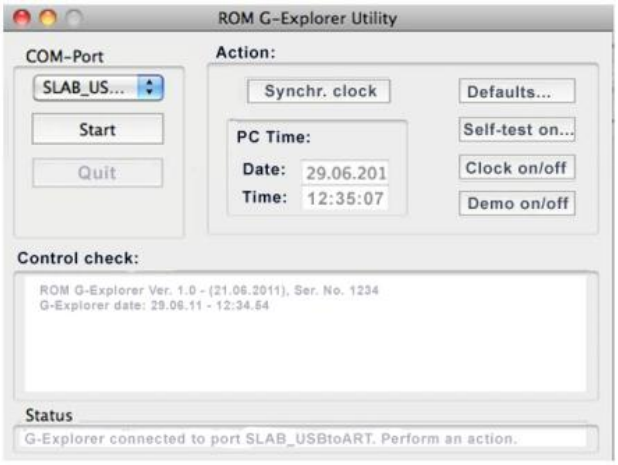
On a Windows© PC, you should be offered a choice of COM ports (COM1…16). Frequently, the one with the highest number is the right one.



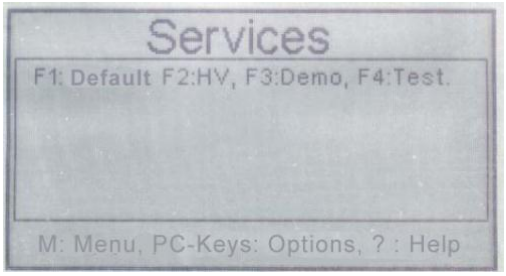
For the Mac OS X operating system, select "SLAB_USBtoUART".



As soon as you click on “Start” in the PC program, it begins communicating with G-Explorer; if the connection is successful, a message appears in the “Control check” dialog box.



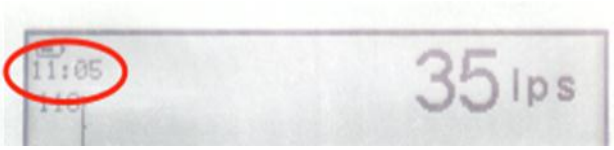
And on the G-Explorer’s screen.



A single click on “Synchr.clock” (Uhr synchr.??) will harmonize the G-Explorer’s time with the PC’s. Make sure you the correct time was set on the PC to begin with.

The remaining options are self-explanatory:

- Factory settings: returns the G-Explorer to the state it came in.
- Self-test: about 4,096 impulses/second are generated internally and displayed when returning to ips mode.
- Clock on/off: choose here if you want the current time to be displayed constantly on the screen beneath the battery symbol
- Demo on/off: choose Demo to internally generate and display random numbers. This is useful for testing functions without a detector.

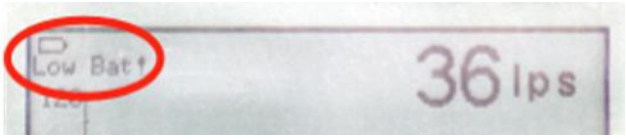


Default setting

Choosing this menu item restores the G-Explorer to its factory settings and returns it to its "as delivered" state.

Battery charge state

The battery's charge state can be read off the battery symbol in the upper left corner of the screen. A low battery charge will result in a "Low Bat!" warning fading into view to let you know that the G-Explorer is due for a battery change, as described in the "Startup" section.



 © ROM-Elektronik GmbH

WORKING WITH DATA

The file contains all the information needed for further analysis and is structured as follows:

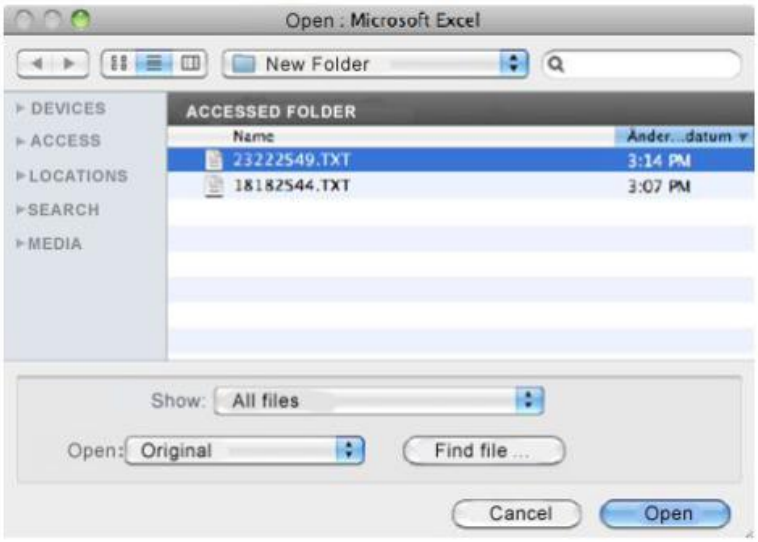
Measured Value No.	Measured value (with decimal point as decimal delimiter)	(if present) GPS data

A data file can look like this, for example:

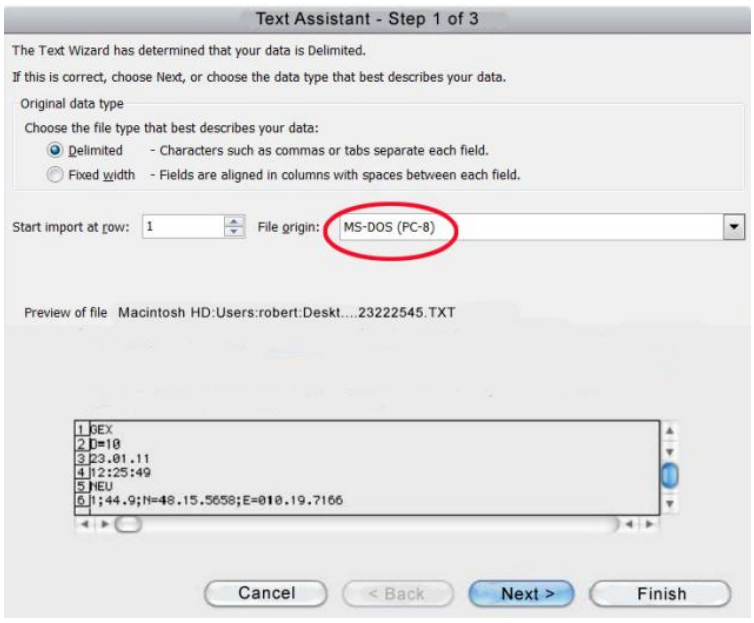
Data file content	Explanation
GEX	Data acquired from G-Explorer
D=10	Distance of 10 units (cm, m, km, inch….)
23.01.11	On 23 January 2011
12:25:49	at 12:25 p.m. and 49 seconds
NEU	New file
1;44.9;N=48.15.5658;E=010.19.7166	Measurement data with GPS coordinates
2;39.1;N=48.15.5658;E=010.19.7166	-ditto -
3;30.1;N=48.15.5658;E=010.19.7166	-ditto-
4;29.1;N=48.15.5658;E=010.19.7166	-ditto-
.....	-ditto-
19;32.9;N=48.15.5666;E=010.19.7199	-ditto-
.....	possibly more data (not shown)
ENDE	End of data records

Beginning on the next page, we show how to import data to EXCEL®

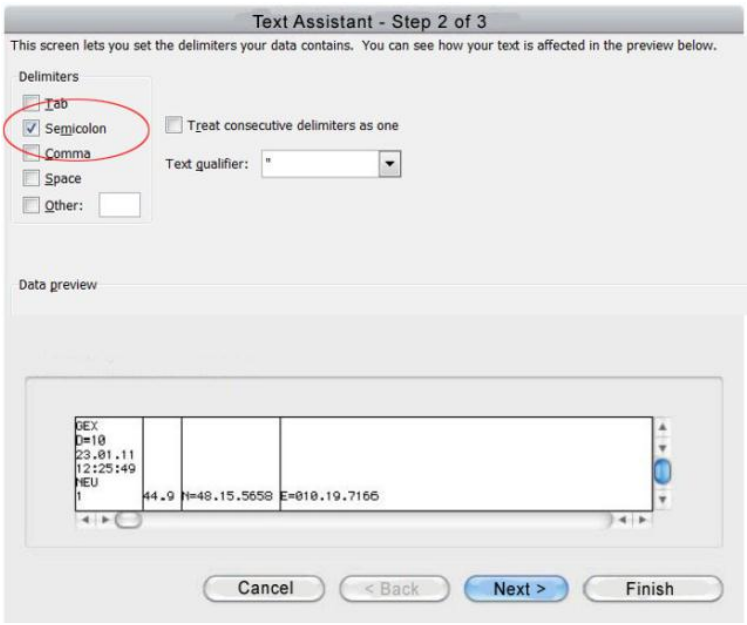
In the Open Excel® dialog box, choose the file containing the measurement data and open it.



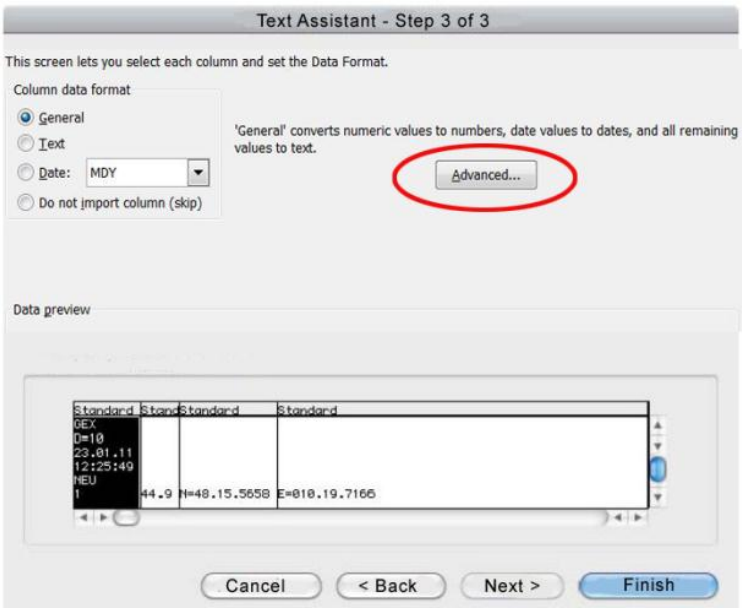
Click the Open button to start the Text Assistant for help with importing the file. Check that "DOS or OS/2 (PC-8") shows as the file source.


Text Assistant - Step 1 of 3
The Text Wizard has determined that your data is Delimited.
If this is correct, choose Next, or choose the data type that best describes your data.
Original data type
Choose the file type that best describes your data:
Delimited - Characters such as commas or tabs separate each field.
Fixed width - Fields are aligned in columns with spaces between each field.
Start import at row: 1
File origin: MS-DOS (PC-8)
Preview of file Macintosh HD:Users:robert:Deskt....23222545.TXT
1 GEX
2 D=10
3 23.01.11
4 12:25:49
5 NEU
6 1;44.9;N=48.15.5658;E=010.19.7166
Cancel
< Back
Next >
Finish

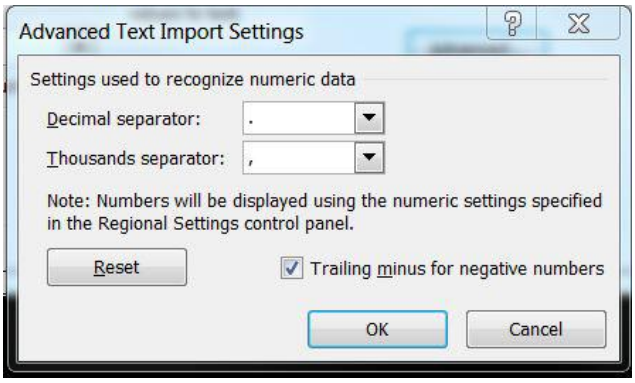
Confirm the choice by clicking “Next” and on the screen that opens now check the “semi-colon” box.



Once more, click “Next” to confirm and open the next window.
Click “Advanced”.

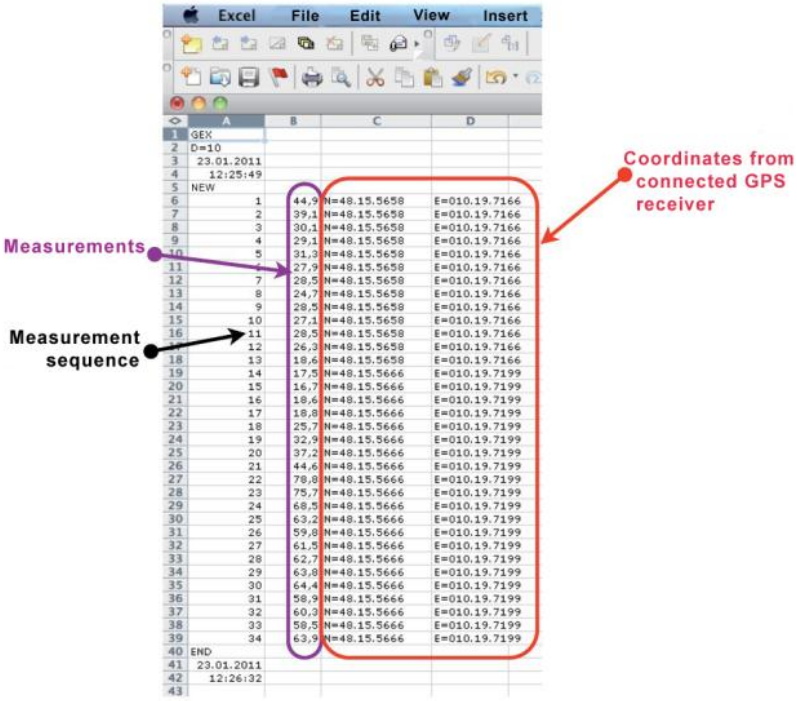


In the dialog that opens next, enter a period (“.”) as the decimal separator to ensure that the spreadsheet calculations will interpret all and not just some of the data as numbers.


Advanced Text Import Settings
Settings used to recognize numeric data
Decimal separator: .
Thousands separator: ,
Note: Numbers will be displayed using the numeric settings specified in the Regional Settings control panel.
Reset
Trailing minus for negative numbers
OK
Cancel

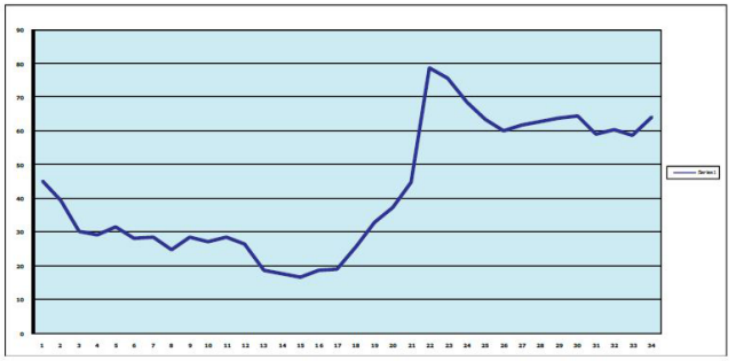
Next, click “OK” to finish the import. This should result in an Excel® spreadsheet with the imported data opening on the screen.

The table in Excel will show all information from beginning to end of the data recording session (date and time); number of measurement value data points; the measurement values themselves and the GPS coordinates, if any, for each value.



Coordinates will only appear if a GPS receiver was used. If a faulty GPS signal was received, the spreadsheet will also contain measurement data without linked coordinates.

The measurement data can be used to create various kinds of graphs. .

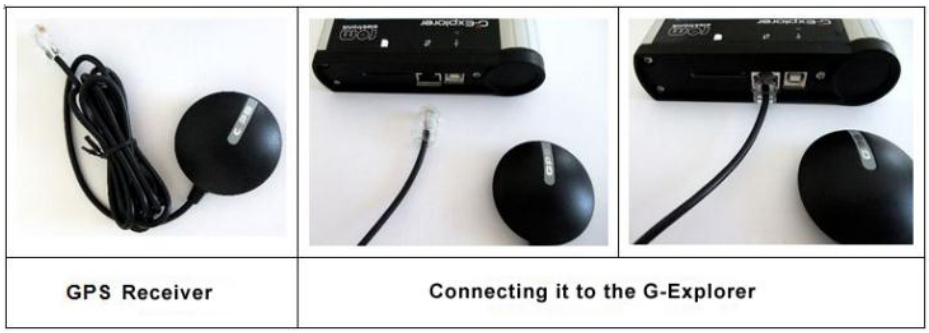


Various kinds of graphs can be created from the measurement data.

Note: The text import procedure described above is for an Apple Macintosh running Mac OS X 1-.6.7 and Microsoft Excel X. It may not work quite the same when using other versions of Excel, other operating platforms or other spreadsheet programs, such as Open Office, Numbers, etc. In that case, please rely on the relevant documentation and user manuals used in your work context. The procedure will be roughly similar to the one illustrated here. If you find yourself stymied, look up how to import CSV-delimited data in your spreadsheet program's user manual.

GPS-RECEIVER OPTION

You can connect a GPS receiver to your G-Explorer and record measurement data linked to GPS coordinates.

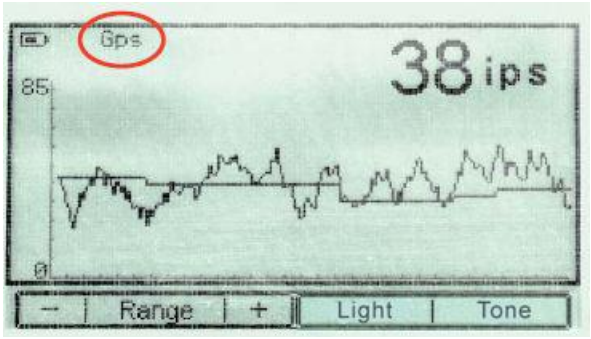


GPS Receiver	Connecting it to the G-Explorer

The GPS receiver we offer for the G-Explorer plugs into the G-Explorer's multi-function port.

WARNING! THE MULTI-FUNCTION PORT IS INTENDED ONLY TO RECEIVE ACCESSORIES CERTIFIED BY ROM-ELEKTRONIK GMBH. ANY OTHER USE CAN RUIN Sensitive ELECTRONICS.

Connect the GPS receiver either before or while the G-Explorer is on. With the G-Explorer



in the "on" state, a red light should appear on the GPS receiver next to the connecting cable.

After approximately 42 seconds, it will begin to blink, indicating that valid data is being received.

By this time, the letters "Gps" will have appeared on the G-Explorer's screen in the vicinity of the battery symbol.

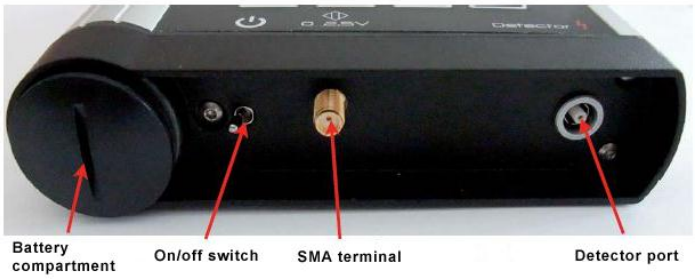
 © ROM-Elektronik GmbH

GPS Receiver Technical Data	
Product specifications	
Chipset	SiRF StarIII
Frequency	L1, 1575.42 MHz
Channels	20
Receiver sensitivity	-159 dBm
Dimensions	53 mm diameter, 19.2mm height
Operating temperature	-30ºC to +85ºC
Accuracy	
Position	5 meters
Speed	0.1 m/s
Processing time	
Quick start	1 sec.
Warm start	38 secs.
GPS Receiver Technical Data	

TECHNICAL DOCUMENTATION

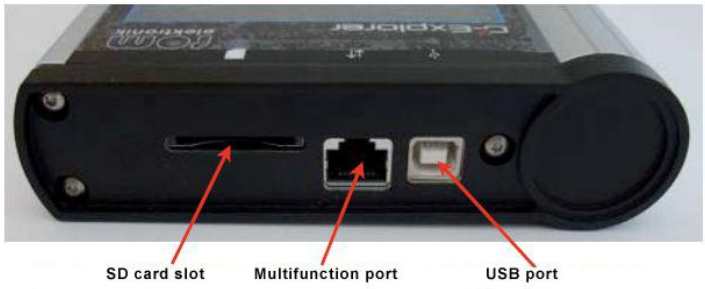
Rear Panel Connections

REAR PANEL



- Battery compartment; takes 4 AA cells
- On/off switch; turns instrument on or off
- Recording device port: SMA analog port delivers 0 – 2.5 Volt; use for connecting to a recording device tuned to the analog graph line on the screen; i.e., the closer the graph line approaches the set range, the higher the output voltage
- Detector port; for connecting the detector with the detector cab
- le provided.

FRONT PANEL



CAUTION! WHEN THE INSTRUMENT IS ON, BOTH THE DETECTOR PORT AND THE LEAD COLLIMATOR'S SOCKET CARRY HIGH VOLTAGE CHARGES!

Front Panel Connections

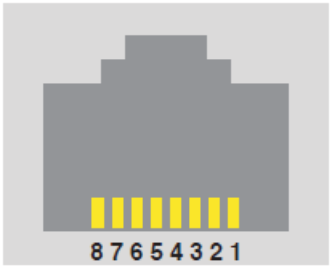
- SD card slot; accepts standard, formatted SD cards.

- Multifunction port: ONLY for use with ROM-Elektronik accessories. THIS IS NOT A NETWORK PORT! Do not connect non-certified devices.
- USB port; for connecting to a computer.

Multifunction port

The G-Explorer's multifunction port only looks like an Ethernet port, but actually carries different signals:

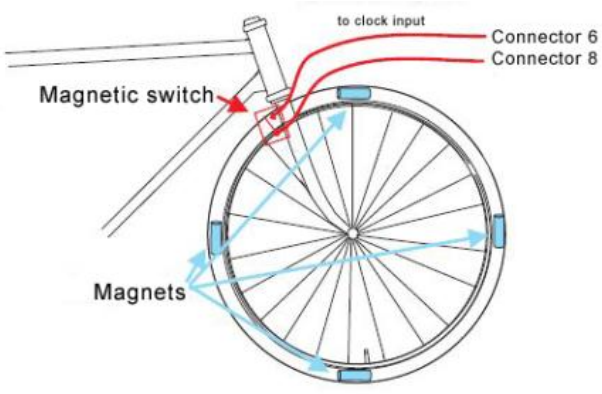
1. I2C Bus SCL (Serial Clock)
2. I2C Bus SDA (Serial Data)
3. Counter input
4. RxD (RS-232 receive line)
5. TxD (RS-232 transmit line)
6. Common Ground
7. + battery voltage
8. Clock input



This is an expansion slot for connecting the GPS receiver or for receiving an external clock signal that is to be saved and the like.

A measurement value is stored whenever the clock input is connected with GND (as long as the "External" option has been activated from the storage menu.)

A surveyor's wheel, for example, an implement that is used for obtaining very exact distance information, can send an external clock pulse. Several magnets are attached to the wheel, along with a magnetic switch. Depending on the wheel's circumference, number and spacing of the magnets, the switch trips every 20 cm, for example, and registers a measurement.

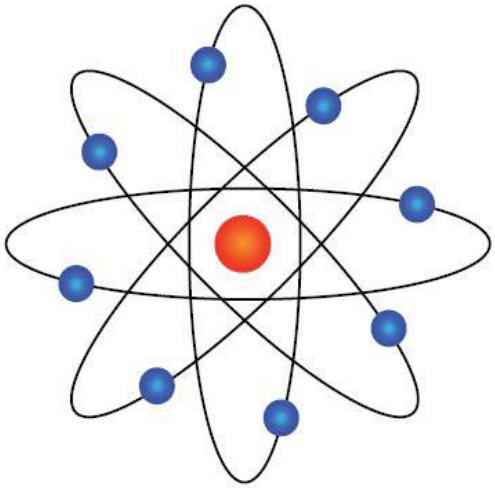


RADIOACTIVE RADIATION

All matter consists of tiny building blocks, the atoms. Atoms consist of a nucleus made up of protons and neutrons, and a nuclear shell made of electrons.

Almost all of the atom's mass is concentrated in the nucleus. The number of protons in the nucleus is its atomic number and identifies the chemical element. The total number of protons and neutrons in the nucleus is its mass number. In general, atoms that are characterized according to their mass number are also called nuclides (Latin for "nucleus"). The mass number is attached to the element's symbol. So, hydrogen can be written either as H-2 or H^2; or carbon, as another example, can be written either as C-14 or C^{14}.

Every element can have various nuclides, differentiated solely by the number of neutrons in the nucleus. They are called isotopes (Greek-and neo-Latin for "same atomic number"). Their chemical properties are completely identical.



Atoms consist of nuclei containing neutrons and protons and a shell made up of electrons.

Ionizing radiation

Radioactive radiation is also called "ionizing" radiation. It refers to the radiation's ability to knock electrons from the electron shell of other, non-radioactive atoms, which then lose their electric neutrality. The atom turns into an electrically-charged "ion," a state in which its chemical properties are completely changed. Besides radioactive radiation, ultraviolet radiation (UV radiation) also has an ionizing effect..

 © ROM-Elektronik GmbH

About radioactive radiation

In general, we differentiate two kinds of radioactive radiation, namely

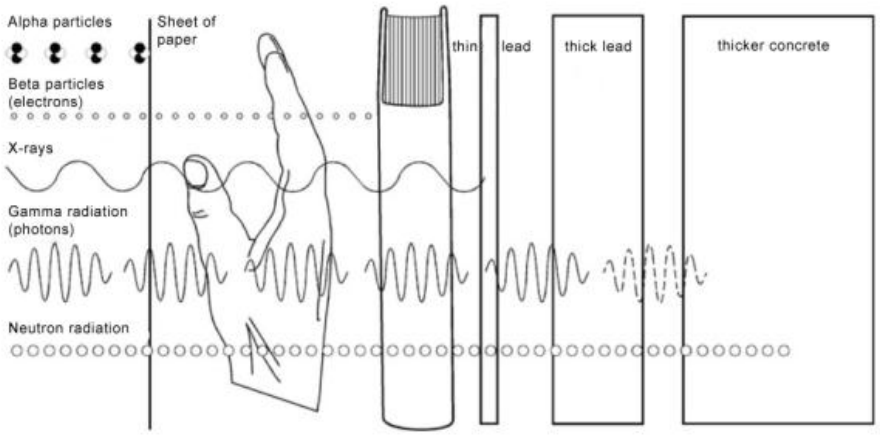
PARTICLE RADIATION (CORPUSCULAR RADIATION)

- α-radiation (alpha radiation)
- β - radiation (beta radiation)
- neutron radiation

QUANTUM RADIATION (ELECTROMAGNETIC RADIATION)

- x-rays ("soft" gamma rays)
- γ radiation (gamma rays)

How effectively radiation can be blocked depends on the type of radiation.



Range and penetrating power of different radiation types

Alpha(α-)radiation

Alpha radiation is a corpuscular radiation that is released by alpha decay of radionuclides. Alpha particles consist of two protons and two neutrons **(=helium nucleus**) that are ejected from a (heavy) atomic nucleus. They possess a double-positive electric charge, which causes α-radiation to be classified as **direct ionizing radiation**. α-radiation's high ionization density, resulting from its high mass (it is 7,294 times heavier than an electron) among densely ionizing radiation types, has a significantly more pronounced biological effect than beta or gamma radiation. This means that, α-radiation causes approximately 20 times more damage than beta radiation, for example, at the same level of activity. α-radiation travels only a few centimeters in air and can be blocked by sheet of paper. It is extremely harmful only if it comes into direct contact with soft tissue (by being incorporated, i.e.breathed in or swallowed.).

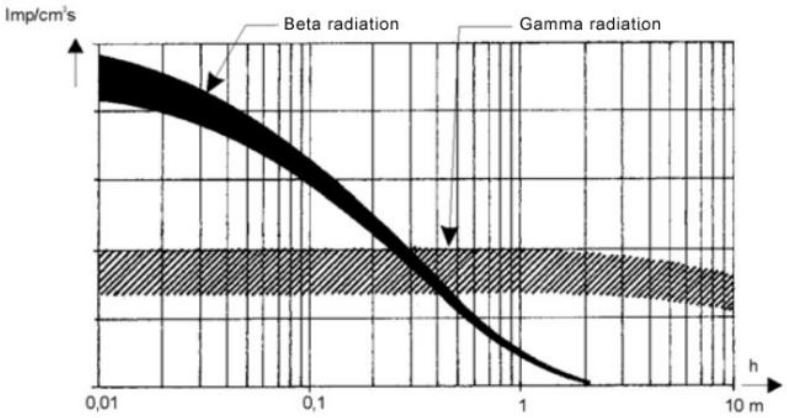
To picture it, think of tissue as young forest and an alpha particle as a car. Even though we can drive our "alpha particle car" only a short distance into the trees, every young tree in its path will be damaged. The damage will be severe.

Beta(β-) radiation

Just like α-radiation, β-radiation is corpuscular radiation released by beta decay of radionuclides. Beta particles are electrons (=negative electric charge) or positrons (=an electron with a positive electric charge) ejected from unstable atomic nuclei.

Although the nucleus is devoid of electrons, because it is being formed spontaneously in unstable nuclei it is still considered as nuclear radiation,. Beta particles also have an electric charge, which also classifies it as **directly ionizing radiation**. Because of the low mass relative to the **loosely ionizing rays**, β-radiation has practically the same relative biological effect as gamma rays. A thick book or a metal plate a few millimeters thick will provide good shielding against beta radiation. In air, β-radiation has a range of a few meters maximum.

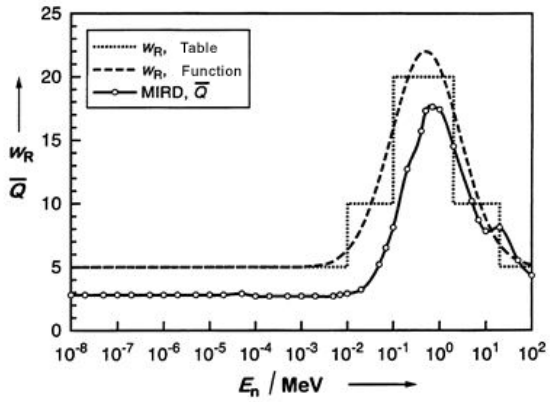
Again, imagine a young forest once more as representing tissue; only this time the beta particle is a motorcycle and not a car. Now, if we ride our "beta particle motorcycle" into the young forest, we are not going damage every tree in our path, just a few. The damage is not as high; on the other hand, we penetrate more deeply – we get farther in with the motorcycle than with the car.



Comparing the ranges of gamma and beta radiation shows that gamma radiation clearly packs more punch beyond 40 - 50 cm.

Neutron radiation

Neutrons are unstable elementary particles without charge that can be created as free



Weighted factors for neutron radiation, according to ICRP 60 (contrasts factors derived from tables with functional factors calculated in practice).

neutrons in nuclear reactions or nuclear fission. Through beta minus decay with a 13 minute

 © ROM-Elektronik GmbH

half-life, a free neutron will decay into a proton. A distinction is made between fast neutrons (kinetic energy of a few MeV) and thermal neutrons (kinetic energy only on the order of magnitude of thermal motion energy). The biological impact of neutrons depends heavily on their energy, ranging between a factor of 5 to 20. Neutrons with an energy of around 1 MeV are particularly potent biologically (RBE=20).

Gamma(γ-)radiation

γ –radiation is a high-energy electromagnetic wave radiation that is generated in the course of radioactive nuclear transformation (i.e., it is an epiphenomenon of α-radiation and β-radiation). It is an indirect, loosely ionizing radiation with high penetration power, which makes shielding against it problematical. It takes at least a few centimeters of lead or concrete to attenuate it to safe levels. It cannot be blocked completely; it can only be diminished to an undetectable level.

Let us picture our young forest again, just this time we are throwing rocks into it. Chances are good that we will hit the random tree here and there, but mostly we will miss and cause little damage – unless we throw a lot of rocks.

X-ray radiation

X-rays are produced when fast electron decelerate upon hitting matter. This effect is relied on to generate x-rays in x-ray tubes. X-ray radiation is actually gamma radiation; but because of the special way in which it is produced and how it is used, a distinction between the two has insinuated itself. About 300 keV is the upper energy limit where we can still call it x-ray radiation. X-ray tubes generate focused x-rays, but some devices will release unwanted x-ray radiation while being operated. In principle, unwanted x-ray radiation generation must be expected any time when working with a device in which electrons are accelerated in a vacuum using high voltages. Examples of such devices are television tubes, computer monitors, oscilloscopes and special tubes that generate microwaves (magnetrons, klystrons).

X-ray radiation emitted by these devices, whose voltages seldom exceed 25kV, consequently has relatively little energy ("soft x-ray radiation"). The radiation's penetrating power is correspondingly low and the housing usually shields it adequately, particularly that for television tubes..

Radioactivity measuring units

Ever since Chernobyl, concepts such as "becquerel" (Bq), "sievert" (Sv), "rem" and others have become terms familiar to all. Here we provide a brief overview of each of these concepts.

Becquerel (Bq) expresses the number of **nuclear transformations per second** (frequently described erroneously as "decays"). **Bq** is thus the unit that measures **activity** in a substance.

If we observe a substance for 10 seconds and find that 100 transformations have occurred during this time (in the form of individual impulses in a detector, for example) we get an activity of 100 transformations divided by 10 seconds = 10 Bq.

Every transformation emits α-radiation and β-radiation accompanied by γ –radiation. Formerly, the "Curie" (Ci) unit was commonly used instead of Becquerel:

$$1\ \text{Ci} = 37\ \text{billion Bq} = 37 \times 10^9\ \text{Bq}$$

When describing the activity of substances, we always speak of **specific activity.** Specific activity is commonly expressed as **Bq/kilogram, Bq/liter, Bq/m^2** and **Bq/m^3.**

Simply stating a substance's activity says nothing about its biological effect. This requires knowing what radiation dose an organism is absorbing.

Radioactive radiation releases energy when it hits matter (the human body, for example).

The unit of measure for the energy absorbed by matter, or its energy dose, is **Gray (Gy).**

1 Gy = 1 J/kg (joule per kilogram)

Formerly, the "rad" (rd) unit was used; it converts at 0.01 rd = 1 Gy.

1 Gy = 0.01 rd.

This gives the energy dose rate Gy/hour..

The extent to which an organism will be damaged by a given, equal energy dose will depend on the type of ray (alpha, beta, gamma, neutron and proton radiation). Each type of ray is assigned a "quality factor" (Q-factor). For gamma and beta radiation Q equals 1, for alpha radiation, it is 20. Put another way, alpha radiation is twenty times more damaging than beta or gamma radiation.

The equivalent dose is calculated as

Energy dose x Q factor

This is expressed by the **"sievert" (Sv)** unit of measure. Only the equivalent dose gives the fact that the different radiation types will produce different biological effects at a given, equal energy dose its proper expression. This is accomplished by using the non-dimensional Q weighting factor, which accounts for the ionization density of each type of ray and further allows taking into account variables such as the type of action (from the outside, or inside) as well as its timing.

1 Sv = 1 Gy x Q

For beta or gamma radiation, Sv = Gy, since the Q factor is 1.

Picture the way skin will tan when exposed to the sun. Let the sun's brightness, that is, the strength of the source, be the activity (becquerel). The increase in the body temperature is equivalent to the energy dose (Gy or Gy/h). Sunlight's spectrum also contain UV rays. Depending on which type of ray it is exposed to, the skin tans or it gets sunburned. This effect on the skin corresponds to the equivalent dose (Sv). The equivalent dose depends on the activity ("brightness"), distance from the radiation source and exposure time.

PLEASE Note: dose = dose rate x time; hence, a dose of 100 µSv can be absorbed from a dose rate of 100 µSv/h in one hour or by 20 µSv/h over 5 hours.

The following chart shows the relationship between the individual units of measure and their effect.

Derived Units	**Surface activity: Bq/cm^2, Bq/m^2 Specific activity: Bq/kg Concentrated activity: Bq/l, Bq/m^3**	**Energy dose rate: today: Gy/h formerly: rd/h**	**Equivalent dose rate: today: Sv/h formerly: rem/h**
Conversions	1 Bq=2,7•10-11Ci 1Ci =3,7•10^{10}Bq	1 Gy= 1 Joule/kg = 100 rd 1 rd = 0,01 Gy	1 Sv = 100 rem 1 rem= 0,01 Sv
Units	today: Becquerel (Bq) formerly: Curie (Ci)	today: Gray (Gy) formerly: Rad (rd)	today: Sievert (Sv) formerly: Rem (rem)
Meaning	Speed of transformation = activity	Energy dose = amount of energy delivered to tissue divided by the irradiated tissue's mass	Equivalent dose = energy dose times a weighted factor
Process	Radioactive substance undergo transformation	and deliver energy to matter, e.g, to the human body	with the strength of radiation varying by the type of radiation

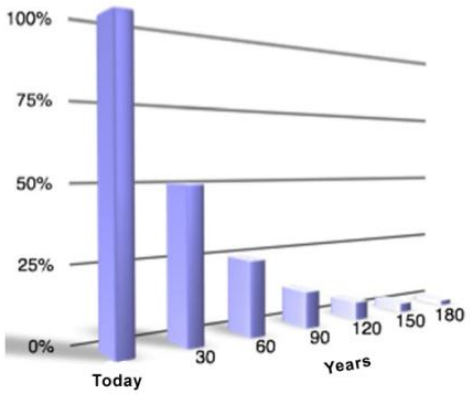
 © ROM-Elektronik GmbH

By way of example, here is the currently prevailing "natural" radiation dose (external radiation exposure) that humans are exposed to (that is, only to β -radiation accompanied by γ –radiation, since α-radiation only has a range of a few centimeters and can be shielded off relatively easily; α-radiation only causes severe damage if it is incorporated). The genetically-significant dose per BGA averages 0.9…1.6mSv/year, with regional variations. We can convert this equivalent dose as described above into Sievert/hour (Q factor = 1; 8,760 hours per year):

$$\frac{1600\frac{mSv}{a}}{8760h} = 0,182\frac{mSv}{h} = 182\frac{nSv}{h}$$

and so obtain a dose rate of between 100…190 nSv/h (nanosievert per hour).

Half-life



Decay behavior of Cs 137, in years

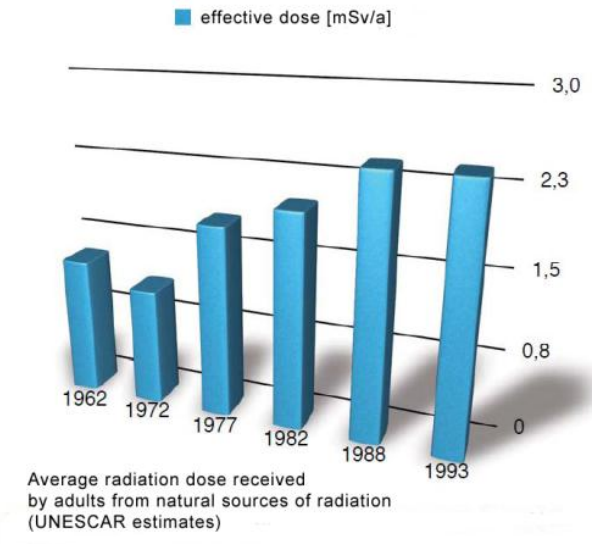
Another distinctive characteristic of radionuclides is their half-life. It is defined as the initial time required for half the number of existing atomic nuclei of a radionuclide to transform into another nuclide's atomic nuclei as it gives off radiation. Each radionuclide has a characteristic half-life. There are radionuclides with very brief half-lives of less than a second, (e.g., polonium Po 214, with 164µs) as well as very long ones, such as potassium K-40, with 1.2 x 10^9 years.

NATURAL RADIATION EXPOSURE

Radiation permeates life and always has. Throughout evolution, humankind has been exposed to the effects of radioactive radiation. In the "normal case" (if we posit an average individual dose of 2.4 mSv/a), natural radioactive radiation exposes every human being externally and internally **every hour** to:

>200, 000, 000	Gamma rays
400, 000	Secondary cosmic radiation
100, 000	Neutrons from cosmic radiation
15, 000, 000	K-40 atoms
30, 000	Radon decay product atoms
7, 000	Uranium atoms

Over the past 30 years, this UNESCAR dose estimate (as of 1993) has climbed 120%. This is primarily because of the increased attention paid to radon exposure. Thanks also to improved international data and progress in lung dosimetry, at present 54% of the total dose due to natural radioactive radiation exposure is ascribed to radon components. It only



Average radiation dose received by adults from natural sources of radiation (UNESCAR estimates)

remains to be seen if further adjustments (upward) will be made in this regard.

A large part of radiation emanates from the ground. Our construction materials, too, come from the ground. A trivial observation perhaps, but it does have great significance for our health, because every building material contains radioactive additives, especially the naturally occurring nuclides radium 226 (Ra-226), thorium 232 (Th-232) and Potassium 40 (K-40), as well as the radioactive derivatives (decay products) of the first two.

The largest number of naturally radioactive substances derives from one of three decay series, whose beginning nuclides have a long half-life relative to the time since the formation of the elements (age of the solar system is about 10 billion years = 10^{13} years.) These are

- the uranium-radium series, starting from uranium 238 (half-life: 4.5 billion years)
- the actinium series, starting from uranium 235 (half-life: 0.7 billion years)
- the thorium series, starting from thorium 232 (half-life: 14 billion years)

Besides the 47 radionuclides belonging to one of the three decay series, there are 18 other radionuclides, some with extremely long half-lives, that have existed since the earth's formation.

Table 4 gives an overview of resulting, additional radiation exposure. The negative value shown for wood is no aberration; it signifies shielding against environmental radiation.

 © ROM-Elektronik GmbH

Contribution of construction materials to radiation exposure in dwellings (Federal Republic of Germany)

Building Materials	Additional Radiation Exposure in mSv/year
Wood	-0.2 - 0
Lime stone, sandstone	0 – 0.1
Brick, concrete	0.1 – 0.2
Natural stone, man-made gypsum	0.2 – 0.4
Slag rocks, granite	0.4 - 2

Research has been conducted for more than 15 years into the radiation exposure caused by radioactive substances in building materials, industrial production and industrial wastes with the goal of keeping the population's exposure to radiation as low as possible.

The following table provides an overview of typical activity concentrations of potassium 40, thorium 232 and radium 226 found in natural stone, binding materials, finished construction materials and diverse industrial products. The specific activity of the radionuclides in the construction materials varies over a wide range. Acidic magma stone, above all granite, evidence relatively high activity from natural radionuclides.

Typical activity concentrations of Potassium 40, Thorium-232 and Ra-226 in different materials (As of: 1992, per German Federal Interior Ministry)

Material	Ra-226		Th-232		K-40	
	Mean	Range	Mean	Range	Mean	Range
Natural Building Materials						
Granite	100	(30-500)	120	(7-311)	1000	(600 - 4000)
Grandiorite	56	(40 - 73)	44	(37 - 104)	850	(380 - 990)
Syenite	30		31		670	
Dolerite	20	(10 - 29)	30	(8 - 44)	290	(22 - 380)
Gneiss	75	(50 - 157)	43	(22 - 50)	900	(830 - 1500)
Diabase	16	(10 - 25)	8	(4 - 12)	170	(100 - 210)
Basalt	26	(6 - 36)	29	(9 - 37)	270	(190 - 380)
Granulite	10	(4 - 16)	6	(2 - 11)	360	(9 - 730)
Greywacke	41	(26 - 51)	35	(13 - 46)	760	(700 - 780)
Phonolite	56		104		1270	
Amphibolite	8		9	(8 - 9)	260	(180 - 310)
Serpentinite	3		7		180	
Quartz porphyry	54	(15 - 86)	77	(53 - 98)	1300	(1000 - 2100)
Prophyr tuff	47	(44 - 52)	206	(133 - 239)	720	(22 - 1700)
Orthophyr	17		22		1300	
Lamprophyre	17	(6 - 30)	12	(7 - 21)	270	(130 - 330)

Augitprophyrite	55	(46 - 61)	67	(57 - 79)	1100	(1000-1300)
Hornblende schist	13		14		380	
Fruit/Phycoden slate	38	(34 - 45)	59	(58 - 73)	780	(760 - 930)
Oolite	19		31		580	
Augite	65		51		970	
Limestone/marble	24	(4 - 41)	5	(2 - 20)	90	(< 40 - 240)
Travertine	4		19		20	
Sandstone, quartzite	20	(13 - 70)	25	(15 - 70)	500	(< 40 - 1100)
Gravel, sand, gravelsand	15	(1 - 39)	16	(1 - 64)	380	(3 - 1200)
Gypsum, anhydrite	10	(2 - 70)	7	(1 - 100)	70	(6 - 380)
Flint	6		1		1	
Kaolin	90	(30 - 200)	100	(70 - 200)	600	(200 - 1000)
Lava	42	(20 - 70)	42	(25 - 60)	720	(490 - 890)
Tuff, pumice	100	(< 20-200)	100	(30 - 300)	1000	(500 - 2000)
Clay, loam	< 40	(< 20-90)	60	(18 - 200)	1000	(300 - 2000)
Finished Building Materials and Binders						
Brick/clinker	50	(10 - 200)	52	(12 - 200)	700	(100 - 2000)
Concrete	30	(7 - 92)	23	(4 - 71)	450	(50 - 1300)
Brick, aerated concrete	15	(6 - 80)	10	(1 - 60)	200	(40 - 800)
Lightweight concrete (non-specific)	30	(< 20 - 90)	30	(< 20 - 80)	1100	(700 - 1600)
Lightweight concrete mixed with						
Pumice	80	(20 - 200)	90	(30 - 300)	900	(500 - 2000)
Expanded clay and slate	30	(< 20 - 80)	30	(< 20-60)	400	(40 - 700)
Slag	100	(20 - 700)	100	(20 - 200)	500	(300 - 1000)
Crushed brick	40	(30 - 70)	60	(30 - 100)	500	(400 - 600)
Hollow blocks	40	(15 - 59)	25	(4 - 52)	320	(60 - 800)
Excelsior light weight sheets	21	(19 - 25)	12	(11 - 14)	210	(50 - 360)
Wall tiles	50	(15 - 100)	55	(25 - 130)	560	(250 - 1000)
Asbestos cement	< 20	(< 20-40)	< 20	(11 - 40)	100	(< 40 - 300)
Fire clay	60	(20 - 100)	70	(40 - 200)	400	(200 - 800)
Oven tiles	74		70		310	
Slag wool	94		31		110	
Whiting	9		2		26	
Cement, non-specific	97	(23 - 330)	20	(11 - 37)	320	(110 - 500)
Portland cement	30	(10 - 50)	20	(10 - 40)	200	(100 - 700)
Slag cement	60	(20 - 1 00)	80	(30 - 200)	100	(< 40 - 200)
Alumina cement	200	(100-200)	200	(100 - 200)	< 40	
Lime, hydrated lime	30	(< 20 - 60)	41	(2 - 93)	150	(20 - 600)
Ready-mix mortar, finishing plaster	30	(< 20-100)	30	(< 20-100)	300	(< 40 - 500)

Raw minerals, industrial waste, other minerals						
Slag						
Cu slag, old production	1500	(861-2100)	48	(18 - 78)	520	(300 - 730)
Cu slag, new production	770	(490 - 940)	52	(41 - 60)	650	(530 - 760)
P-slag	53	(32 - 86)	74	(65 - 82)	170	(58 - 270)
Ni-slag	52		78		76	
Ni-Mn slag	311		37		710	
Al slag	14	(12 - 16)	8	(6 - 9)	750	(360 - 960)
Fe-Cr-Si slag	9		6		10	
Sn slag	1100	(1000-1200)	300	(230 - 340)	330	
Open hearth slag	20		7		22	
Pb slag	270		36		200	
S slag	12	(8 - 15)	< 10		58	(30 - 85)
Refining slag	19	(17 - 23)	6	(5 - 8)	20	(10 - 34)
Thomas slag (Belgium)	19		-		-	
Steel slag	13		7		21	
Cupola furnace slag	110		47		210	
Blast furnace slage	1000	(980 - 1100)	286	(260 - 310)	n. g.	
Boiler slag	68	(24 - 110)	54	(7 - 120)	200	(20 - 330)
Blast furnace slag	100	(40 - 200)	100	(30 - 300)	500	(200 - 1000)
Mine tailings	700	(36 - 5900)	70	(27 - 100)	700	(40 - 1200)
Process residues (non-uranium industry)	170	(9 - 310)	84	(3 - 250)	130	(1 - 280)
Brown coal filter ash	82	(4 - 200)	51	(6 - 150)	147	(12 - 610)
Fly ash, non-specific	200	(26 - 1110)	100	(14 - 300)	700	(170 - 1450)
Chemical gypsum from:						
Apatite	60	(40 - 70)	< 20		n. g.	
Phosphorite	550	(300 - 1100)	< 20	(< 4 - 160)	110	(< 40 - 300)
Flue gas desulfurization	8	(3 - 70)	6	(4 - 20)	50	(< 20 - 80)
Fluorspar	35		8		280	
Barite	180		17		350	
Feldspar	60	(40 - 100)	100	(70 - 200)	3000	(2000 - 4000)
Bauxite (Hungary)	170		100		< 20	
Bauxite (Zaire)	240		120		< 30	
Bauxite (Guayana)	33		170		66	

Bauxite (red mud)	200	(< 20 - 800)	400	(50 - 1000)	400	(<20 - 1000)
Iron ore (Brazil)	22		4		n. g.	
Iron ore (India)	21		2		27	
Rock phosphate (non-specific)	1000	(100-2000)	40	(< 20-100)	500	(<40 - 900)
Apatite (CIS)	30		60		100	
Phosphate (CIS)	390		25		230	
Phosphate (Morocco)	1800		26		n. g.	
Phosphate (CIS – Koala)	59		64		n. g.	
Magnetite (Erz Mountains)	44		3		52	
Microlite concentrate (Mozambique)	120000		11000		n. g.	
Tantalite concentrate (Mozambique)	14000		390ß0		n. g.	
Monazite sand (India, Sri Lanka)	600	(30 - 1000)	2000	(50-3000)	40	(< 40 - 70)
Monazite concentrate (Mozambique)	36000		84000		n. g.	
Silver concentrate (Erz Mountains)	140		150		5200	
Expanded clay and shale	40	(< 20 - 70)	70	(30 - 90)	600	(70 - 800)
Pumice slag	170	(110 - 230)	43	(24 - 62)	190	(180 - 190)
Claydite	37		51		690	
Fertilizer (non-specific)	400	(< 20-1000)	< 20	(< 20 - 30)	4000	(< 40 - 8000)
Superphosphate						
•Germany	375	(230 - 520)	30	(15 - 44)	96	(52 - 140)
•USA	785	(780 - 790)	34	(20 - 48)	-	
•CIS	110		44		120	
•Belgium	910		< 25		< 180	
PK fertilizer (Germany)	370		15		5900	
PN fertilizer						
•Germany	310		30		41	
•CIS	460	(100 - 820)	29	(10 - 48)	-	
•USA	115	(20 - 210)	39	(15 - 63)	-	
NPK Fertilizer						
Germany	270		15		5200	
CIS	9		54		1200	
Belgium	210		< 15		5900	
Coke	30	(20 - 30)	< 20		70	(40 - 80)
Hard coal	32	(4,7 - 145)	21	(4,8 - 63)	225	(7 - 700)
Brown coal	10	(< 1 - 51)	8	(< 1 - 58)	22	(< 4 - 220)
Bitumen, tar	< 20		<20		110	(37 - 260)

 © ROM-Elektronik GmbH

Generally speaking, we can say that sand, gravel, limestone and gypsum only contain minor amounts of radioactive substances. By contrast, some tuff, pumice, granite and other rocks in many instances are more highly burdened. These construction materials should be largely avoided in building homes. Clear up any doubts by doing a radiation measurement. Although most granite slabs exceed the guidelines, it is entirely possible to find one whose radioactivity lies below the suggested guideline value. Large variations in radioactivity are possible, depending on where the building material originates from.

An advisory commission created by the Federal Ministry of the Interior has recommended the following formula for use in living and gathering spaces:

$$\frac{A_{Kalium}}{4810\frac{Bq}{kg}} + \frac{A_{Radium}}{380\frac{Bq}{kg}} + \frac{A_{Thorium}}{259\frac{Bq}{kg}} \leq 1$$

(A = activity of the respective substance in building material)

The formula says that when it comes to building materials, the sum of the radioactivities of potassium, radium and thorium, each of them divided by a factor that expresses the degree of danger each radionuclide harbors, should be no higher than 1.

This is designed to ensure that radioactivity deriving from building materials will not surpass 1.5 millisievert per year (1.5 mSv/annum = 1,500 µSv/a = 150 mrem/a)

Wood used for building houses sourced from the Ukraine can carry an elevated radiation burden in comparison with domestic wood. Greetings from Chernobyl! In general, however, it is still lower than for a house built of stone. In measuring a house built in 1995 with Ukrainian wood, direct contact resulted in an elevated radioactivity of ca. 150 nSv/h where the background radiation was ca. 85 nSV/h. When measured from a distance of 1 meter from the walls, no measurable increase could be detected in the house.

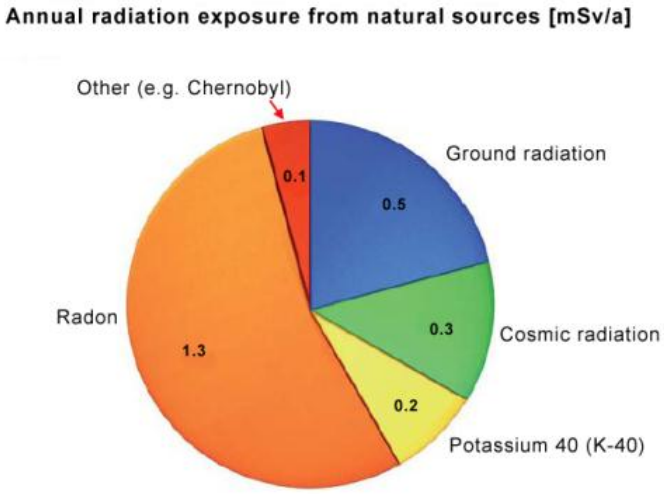
As clearly illustrated by this example, often just 50 – 100 cm distance from radioactive walls is enough to markedly reduce incremental radiation exposure,.

Natural radiation exposure in Europe amounts to approx. 2.4 millisievert per year (2.4 mSv/annum; UNESCAR estimate). 0.01 mSv/a (= 10 µSv/a =1 mrem/annum) of this derive from nuclear facilities. This radiation burden, broken down by individual components in the following table, can vary greatly from region to region.

Annual radiation exposure from various sources.

	Mean	Variation
Ground radiation	0.5 mSv/a	0,2-1,5 mSv/a
Cosmic radiation	0.3 mSv/a	0,3-1,2 mSv/a
Potassium 40	0.2 mSv/a	-
Radon	1.3 mSv/a	0,2-2 mSv/a
Other (e.g. Chernobyl	0.1 mSv/a	-
Total	**2.4 mSv/a**	**1-5 mSv/a**

For example, we have measured differences of 75 nSv/h to 140 nSv/h within a 40 km circle. The following chart summarizes the sources of our radiation exposure. Radon is noticeably the largest source, closely followed by ground and cosmic radiation.



The value shown for K-40 also includes our own body's radiation. All humans have a certain quantity of potassium in their bodies. Part of it is the radioactive nuclide K-40. In a manner of speaking, every human "glows" with about 3,000 – 5,000 Bq, just from potassium.

Tiles and Flagstones

Unlike building materials whose radioactive radiation stems mostly from evaporating radon and its decay products, tiles and flagstones emit direct radiation. Not all tiles and flagstones are radioactive emitters, but uranium was and is used to achieve certain glaze colors, especially green and red.

Since May 31, 1981, only 2 milligram uranium per square centimeter has been allowed, whereas earlier the uranium content in ceramic glaze could be as much as 20%.

This does not mean that every residence has radioactive tiles and flagstones in it; in fact, the opposite is true. These strong emitters are actually found rather infrequently. The question of how much radiation exposure there is does not have an easy answer. It depends heavily on the individual circumstances.

As a rough point of reference, here are the results of a test during which the radiation exposure from flagstones was measured at various distances.

While the additional equivalent dose at 5 cm distance amounted to 23 microsievert (23 µSv = 2.3 mrem) per hour, at a distance of 90 cm it was found to be 12 µSv/h. Taking into account the shielding effect of clothing and supposing that half an hour is spent daily in the vicinity of the radioactive tiles, the annual radiation exposure amounts to about 1.1 mSv (=110 mrem).

Recommendations

The chance of coming across radioactive flagstones or tiles is relatively low. It increases somewhat if these flagstones or tiles were laid down some time ago (before 1985 or thereabouts) and they came from Italy.

If is determined without doubt that strongly radiating flagstones or tiles are present, they should be removed if possible or new ones installed over the old ones..

A carpet with rubberized backing reduces beta radiation from uranium-containing flag stones or tiles by about 30%.

 © ROM-Elektronik GmbH

MEASURING RADON

The procedure described here is a tried and true, older method for measuring radon decay products. Use it where measuring **sensitivity needs to be high and time is short.**

We use a vacuum cleaner and a portable scintillation detector (G-Explorer). The professional variant employs a so-called high volume sampler, a large-area Geiger counter or a gamma spectrometer with germanium detector. The sampler is a vacuum cleaner-like blower with volume meter.

The idea is rather simple: the vacuum cleaner suctions the air to be tested through a measuring filter (in case of the professional type), then we measure the activity in the filter with the gamma detector.

Here you will learn the details of how to take a useful measurement.

Gamma measurement is a thoroughly user-friendly procedure, that can be done almost without watching the clock and without stress. Sampling time, delay until the activity measurement and the time for the activity measurement can vary widely without producing a false result.

The short time required for the measurement is both an advantage and a drawback. Experience tells us that radon concentrations in living spaces can fluctuate markedly with time, as much as by a factor of 10 in half an hour. In no way does it represent the long-term mean value for someone residing in a home. Measurements taken during the day usually are too low, as the radon concentration is usually higher at night. On top of that , with several people moving around the home while the test is taking place, the increased air circulation reduces the radon concentration.

The procedure does deliver a realistic measurement, but it can only serve as a general point of reference. You should employ a commercial vendor to conduct testing over an extended timeframe before making any decision to have the house decontaminated.

SUMMARY OF THE MEASUREMENT PROCEDURE

- G-Explorer set to either time or impulse mode (as desired). Measuring times of about 5 minutes (=300 seconds) or setting it to about 5,000 impulses are good reference values.
- Start background measurement
- Position filter in or on the holder
- Vacuum for five minutes, while taking background readings
- Fold the filter (as described in the text)
- Place filter in the detector (see text)
- Turn on G-Explorer in either time or impulse mode. Apply approximately the same parameters used for the background measurement.
- Read off the gross ips
- Do the analysis

The measuring filter

Als Filter sind Glasfaserfilter der Klasse S gut geeignet. Sie lassen viel Luft hindurch und scheiden die Radioaktivität zu 99% ab. Kaffee- oder Staubsaugerfilter lassen in der Regel zu viel Staub und damit Aktivität hindurch. (Anmerkung: Radongas wird nicht gesammelt, es geht vollständig durch das Filter durch.) Andere Filter sind vielfach dicht genug, lassen aber zu wenig Luft hindurch.

ROM-Elektronik sells a suitable filter holder and filter (**NOT** included in the G-Explorer package).

MEASURE THE BACKGROUND RADIATION

All scintillation detectors pick up ambient or background radiation, including during the measurement phase with filter. It must be measured first so that it can be subtracted later on.

The lower the background radiation, the more accurate the ensuing measurement with filter will be. Look for a place with the least possible background radiation where to set up the detector.

Support the filter while the measurement is in progress to keep it from tearing. This can be done by means of a filter holder like the dust catcher mounting. .

VACUUMING

This is when you run the risk of having your vacuum cleaner burn out. Don't let it happen! The lower the volume of air moving through a vacuum cleaner is, the lower is the load on it and the faster the motor runs. The air stream simultaneously cools the motor (that is what led to the invention of the 1,000 watt vacuum cleaner). The motor overheats if not enough air flows through it. It suffers thermal overload, even though it is working less. The key is to find a practical compromise between air volume, sampling time and motor temperature. This is up to you; we can't be responsible for your vacuum cleaner.

Nevertheless, here are a few tips: Always **use the same, unused vacuum cleaner bag** so that you don't have to repeatedly measure the air flow anew. Without a bag you will destroy the motor windings, should the vacuum cleaner accidentally suck in a foreign object. Operate at the highest setting for a shorter collection time. Five minutes sampling time works well in practice. Shut down if the exiting air becomes warmer than when vacuuming carpets. Be sure to remain close by.

You have to know the volume of the vacuumed measured air. The sampling time itself is less important. This requires calibrating your vacuum at least once, meaning that you have to know the air flow in cubic meters per minute (m^3/minute). You should regularly recalibrate since vacuum cleaner performance characteristics do change.

 © ROM-Elektronik GmbH

CALIBRATE THE VACUUM CLEANER

The basic idea is to first simply inflate a light plastic bag (such as a trash bag) and, through a measurement filter, vacuum it empty it again. You measure the inflated bag and calculate its volume, then use a stop watch to time how long it takes to empty it. There are a number of ways to do this, but the method described here is one that we have tested.

Obtain a bag that fits a 240 liter trash can. It will have a volume of about 400 liters in this intended use. Using a plastic sealer device (as used for freezer bags), weld the opening shut, leaving only a smallish hole in the middle but large enough to accommodate the filter with filter holder. Place a filter on the holder. Attach the holder to the vacuum cleaner's suction tube, then insert the holder with filter into the trash bag. Wrap a small amount of bag at the opening around the suction tube and fasten it tightly by slipping a rubber band over it.

Remove the vacuum hose from the vacuum cleaner then turn it on. Now hold the hose end loosely in front of the exhaust opening until the bag is fully inflated. Turn off the vacuum and remount the hose on the intake opening. No need to rush, with the bag more or less airtight.

For the measurement, set the bag upright. Its shape should be nearly cylindrical. Measure its height and the diameter or circumference (with a string). Write down all measurements in decimeters (1dm – 10cm). Lay the trash bag on its side again. Turn on the vacuum cleaner and at the same moment start your stopwatch.

Now, as the bag starts to shrink, carefully roll up its bottom end loosely to keep the top from collapsing and prematurely blocking the filter. Push your stopwatch again when the bag is empty..

CALCULATE THE AIR FLOW IN M^3/MIN:

You have measured the bag's diameter or circumference and its height in decimeters (dm) and the time in seconds.

From that, you first get the volume in m^3:

$$Volume = \frac{height \times diameter^2 \, x \, \pi}{4{,}000}$$

$$Volume = \frac{height \times circumference^2}{4{,}000 \, x \, \pi}$$

From volume and time you obtain the airflow in m3/minute:

$$Airflow = \frac{Volume \times 60 \, sec}{Vacuum \, Time}$$

Tip: to achieve professional accuracy, place the plastic bag inside a cage carefully constructed out of chicken wire.

EXAMPLE 1

Circumference = 2.4 m = 24 dm
Height = 100 cm = 10 dm
Vacuum time: 55 seconds

$$Volume = \frac{height \times circumference^2}{4{,}000 \, x \, \pi} = \frac{10dm \times 24dm \times 24dm}{4{,}000 \times 3.14} = 0.459m^3$$

$$Airflow = \frac{Volume \times 60\ sec}{Vacuum\ Time} = \frac{0.459m^3 \times 60\ sec.}{55\ sec.} = 0.50\frac{m^3}{min.}$$

EXAMPLE 2

Circumference = 70 cm = 7 dm
Height = 100 cm = 10 dm
Vacuum time: 1 minute 55 seconds = 115 seconds

$$Volume = \frac{height \times diameter^2\ x\ \pi}{4{,}000} = \frac{10dm \times 7dm \times 7dm \times 3.14}{4{,}000} = 0.385m^3$$

$$Airflow = \frac{Volume \times 60\ sec}{Vacuum\ Time} = \frac{0.385m^3 \times 60\ sec.}{115\ sec.} = 0.20\frac{m^3}{min.}$$

MEASURE THE FILTER

G-Explorer's scintillator crystal has a 2" diameter =5 cm. The filter's size is about 8.5 cm so we have folded it three times, with the vacuumed side top. Fold the filter from its right edge over to the left third, then from the left edge all the way to the right third (which now is the right edge). Repeat for the upper and lower edges, making a square filter about 3 x 3 cm in size. The activity is on the inside and mostly in the middle. Use a small rubber band to keep the packet from unfolding again.

Now the filter should be as close as possible to the detector. We are using G-explorer, which is why we place the filter on a plastic sponge cut into a circular shape, before shoving the whole thing into the lead shielding.

Start in stationary mode, with duration or impulse set to a few minutes..

DO THE ANALYSIS

The object is to determine the concentration of radon decay products in the air from the sample air volume and the impulse rates. Since we are measuring gamma radiation, the analysis is easy, because a single calibration factor (within our measuring accuracy framework) is sufficient. You can calculate the required calibration factor from the half-lives of the radon decay products, the composition of the related airborne mixture and the detector's efficiency. The latter must be found experimentally (calibration source). We determined this value indirectly from comparative measurements with a commercial decay product measuring instrument, the Working Level Monitor 200 plus by Tracerlab Instruments.

The calibration factor is exactly 3.5 Bq/ips for the activity mixtures that most often manifest in dwellings. This means that for every measured net impulse per second there is a 3.5 Bq/m^3 equilibrium equivalent radon (EER) concentration.

Please follow the analysis guide presented below.

 © ROM-Elektronik GmbH

MORE MEASUREMENT TIPS

Fold the filter so that most of the activity winds up on the inside in the middle, otherwise you will contaminate the measuring instrument and impair the detector's reactivity.

CAUTION! DON'T TOUCH THE COLLECTED RADIOACTIVITY WHEN FOLDING THE FILTER. ANYTHING THAT STICKS TO YOUR FINGERS WILL BE MISSING FROM THE MEASUREMENT SAMPLE.

Analyzing a G-Explorer radon test

After completing the measurement procedure, you should have on hand or at least know the following:

- Calibration factor in Bq/m^3
- Filter airflow in m^3/minute
- Collection time in minutes
- Background impulse rate (null effect) in ips (impulses per second)
- Gross impulse rate with filter, in ips

To start with, calculate the collected volume of air in m^3

$$Volume = Airflow \times Collection\ time$$

The resulting net impulse rate is

$$Net = Gross - Background\ radiation$$

The concentration of radon decay products (potential α radiation) in form of the equilibrium equivalent radon (EER) concentration therefore amounts to (in Bq/ m^3):

$$EER = \frac{Calibration \times Net}{Volume}$$

REMARKS:

Radon gas concentration in a typical home is approximately double that of the decay products. This rule does not apply outdoors, where the difference is usually smaller; in especially small rooms, where the difference is often larger; and in rooms with high EER and good ventilation, where the difference is also larger. Both the SSK[1] and the ICRP[2] assume the ratio is 2.5 times..

[1] SSK = Strahlungs Sicherheits Kommission, Germany's Radiation Safety Commission
[2] ICRP = International Commission on Radiological Protection

Analysis examples

EXAMPLE 1

Calibr = 3.5 Bq/ips (fixed calibration factor)
Airflow = 0.5 m^3/min (typical for certain filters and vacuums)
Collection time = 4 min. 30 seconds = 4.5 minutes (measured)
Background = 19.5 ips (measured)
Gross = 83 ips (measured)

Result:

$$Volume = 0.5\frac{m^3}{min.} \times 4.5\ min. = 2.25m^3$$

$$Net = 83ips - 19.5ips = 63.5ips$$

$$EER = \frac{3.5\frac{Bq}{ips} \times 63.5ips}{2.25m^3} = 99\frac{Bq}{m^3}$$

REMARKS

This value is not to be compared with the upper value of the normal range for radon gas according to the German SSK (250 Bq/m3, but instead with the ICRP's more precise specification (100 Bq/m3 radon decay products), from which the German value is derived, with certain assumptions. So it seems we have landed on the borderline between normal and elevated radioactivity. Meaning: "measure it again!" If a comparison with SSK recommendations must absolutely be made, the calculated result will do. The calculation method is identical to the one used by the SSK.

EXAMPLE 2

Calibr = 3.5 Bq/ips (fixed calibration factor)

Airflow = 0.2 m^3/min (a smaller vacuum cleaner than in Ex. 1)

Collection time = 5 min (pre-determined)

Background = 25 ips (measured)

Gross = 213 ips (measured)

Result:

$$Volume = 0.2\frac{m^3}{min.} \times 5\ min. = 1m^3$$

$$Net = 213ips - 25ips = 188ips$$

$$EER = \frac{3.5\frac{Bq}{ips} \times 188ips}{1m^3} = 658\frac{Bq}{m^3}$$

 © ROM-Elektronik GmbH

REMARKS:

This value is not to be compared with the upper value of the normal range for radon gas according to the German SSK (250 Bq/m3, but instead with the ICRP's more precise specification (100 Bq/m3 radon decay products), from which the German value is derived, with certain assumptions. So it seems we are far above normal range. If this is a space which someone enters only sporadically (e.g. a storage basement) there is no need for countermeasures. Much more important would be to thoroughly check the rooms where people spend a lot of time.